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THE CONTINUOUS GIRDER QUESTION.

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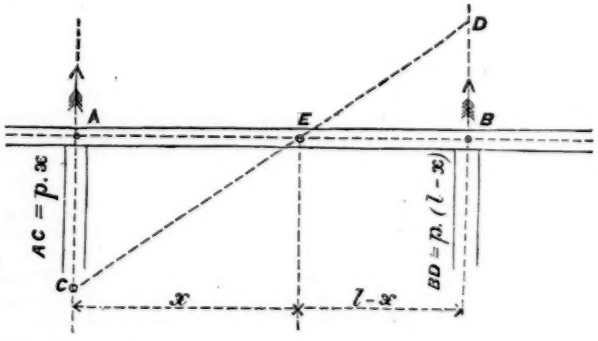
On page 152 of the August number of VAN NOSTRAND'S MAGAZINE, the author (Mr. Merriman) says:

"*As far as the diagonals are concerned the two structures* (the one of 7 continuous spans of 50′, the other of 7 single spans of 50′ each under uniform dead load) *require an equal amount of material.*" This is mathematically wrong, and it requires a limited amount of theory to see it.

Be A B a span of a continuous bridge



uniformly and wholly loaded by p pounds per lin. foot. C D may represent the line of shearing forces, A C being the reaction on A equal to $p.x$, and B D being the other reaction $=(l-x)\,p$.

It is well known that of a continuous bridge even if uniformly loaded (for instance, by dead load)—save in the middle span in case of an odd number of spans—the reactions A and B, arising from the load A B, are *not equal*, or that C D does not pass through the center point of A B.

The quantity required in the web of span A B is equal to the sum of the triangles A C E plus E B D, multiplied with a certain constant coefficient; and since A E $=x$, and B E $=l-x$, there is the:

$$\text{Web} = \text{coefficient} \times [x^2 + (l-x)^2]$$

This is *no* constant function; it has a minimum which occurs for $x=l-x=\frac{p}{2}$, in other words:

The theoretical value of the web of a single span bridge, even for uniform load, is lighter than it would be for a continuous bridge.

For single spans, there is the web= coefficient$\times\frac{l^2}{2}$, and for two continuous spans the web is = coefficient$\times 0.531l^2$, which is 6.2 per cent. more than for single spans.

The author further says, on page 153: "It is capable of demonstration that for girders subjected only to dead load the total amount of strain of the webbing will be the same as for continuous trusses."

Also this assertion is theoretically wrong, and, like the last proposition, is not capable of demonstration.

Practically, in case of many spans, the webbing of continuous bridges would only be slightly greater than for single spans, were it not that the *movable* load influences continuous girders *very materially* more than it does single spans. (Compare figures on 200′ spans given in the sequel). Our instructor, in speaking of the variability of the moduli of elasticity, towards refutation of my own paper on "Continuous Bridges" (written for the use of the American Society of Civil Engineers, Transactions volume V, 1876), quotes a passage of Gen. Morin's book, on the properties of building material, which very passage I have alluded to on page 159 of the Transactions quoted, where I said: "Morin believed that the great variability of moduli (even of rails of same section and make) should be explained by the quality of the iron, and he judges that the better material should show also the higher modulus. But the great variations also of moduli of bars, of undoubtedly excellent make and of great uniformity, seem to disprove his judgment." It is interesting to know what Morin says just *before* the passage translated by Mr. Merriman, and also what he says *after* that passage.

These two additions prove that Morin puts his classification down only as a *hypothesis*, which is all to what he is really entitled. General Morin says: "It is *pretty difficult to determine* with exactness the *average value* of moduli of elasticity of wrought iron to suit all the results of old and new experiments. It *seems* to me to be *more convenient* (*plus* convenable) to establish a distinction between the different qualities of iron which can be procured in the market." And after classifying, as translated, into high grade (average modulus 30 million pounds), ordinary iron (modulus, 25,000,000), and soft, ductile iron (modulus, from 21 to 17 million pounds).

Morin says: "But, moreover, it must not be lost sight of that it happens *pretty often* that iron bars of the *same* manufacture, furnished by the *same* works, present *notable* differences in their resistance to flexure, such as have been seen in No. 368, where the results of experiments on the flexure of rails, made in the conservatory, are reported."

In order to be fair, the translator should have given also these passages which immediately inclose the one given, and which are indispensable to the understanding of this question. Actually, the experimental results quoted by the General hardly permit his hypothesis of the *cause of variability of moduli*. Had General Morin been in possession of the many other experimental results, collected and related by me, he most probably would not have drawn his hypothetical generalization.

Thus, not only common iron, but also the superior Reschitza steel, shows moduli from 24,600,000 to 27,700,000 pounds. The great variability of moduli is further illustrated by Prof. Bauschinger's experiments on Bessemer metal from Ternitz. The softest metal of this make, containing only one-seventh of one per cent. of carbon, which represents fibrous iron of great ductility, and stretching permanently from nineteen to twenty-five per cent., showed moduli from 28,400,000 to 38,200,000 pounds. Again, superior English crownbars, and the iron tested by Hodgkinson (quoted by Morin), shows moduli from 23,440,000 to 20,660,000 pounds.

All this proves that refining and stock alone are not sufficient to clear up the cause of the variations of moduli. The experiments made by the Prussian State Engineer (Baurath) Malberg, in 1845, for the bars of the Muehlheim suspension

bridge, gave moduli from 20,000,000 to 27,000,000 pounds. These bars were made of the same excellent quality of "*coldblast charcoal*" stock from the famous Siegen sparry ores. It was *puddled*, *hammered* and *rolled* into muck bars. These were *piled*, charged to *heating* furnaces, hammered under a *six-ton steam hammer*, *reheated* and *rolled* into bars of $6'' \times 1\frac{1}{2}''$, and of about 8′ length. The manufacture was done with the greatest possible care, and so as to secure the greatest possible uniformity. Here, then, is charcoal pig-iron treated under most approved processes, which would fall in the class No. 1, or should show the highest moduli of 30,000,000 in average as per Morin. But the average modulus is only 24,000,000 pounds.

The experiments (fall, 1875) of Mr. Th. Lovett, consulting and acting engineer of the Cincinnati Southern Railroad, were made on thirty different compression members from ten to thirty feet long, such as are *actually used* in the first-class bridges (from the Keystone, the American, Phœnix and the Baltimore Bridge Companies), and it is quite positive that these members were as well made in every regard as could, or as can, be expected from manufacturers in any country. The moduli found extended over a range from 19,300,000 to 34,600,000 pounds. There were:

Below 20 million pounds	1 moduli.
From 20 to 25 million pounds.....	7 moduli.
From 25 to 30 million pounds.....	15 moduli.
From 30 to 34, 6 million pounds...	5 moduli.

I have tested many thousand eye-bars in the lever machine at Phœnixville, all under the same strains below the elastic limit (20,000 lbs. square inch is the customary applied test load). The bars were long bridge members, and constitute parts of existing structures. Wooden rods 15′—20′ long were clamped at one end to the bars, and, it was found by careful measurement, 1, that hardly a difference in the moduli was observable as long as these best-best bars were of the same lot, that is of the *same section* and length; 2, but that the moduli were very differing for *different cross-sections* of bars. Thin bars—perhaps, because finished in the rolls colder than thick bars—gave the lowest moduli, such as 18,000,000 pounds, whilst the maxima were obtained for bars of $6'' \times 2\frac{3}{8}''$, whose moduli went up as high as 40,000,000, and even more pounds. Other engineers, like Mr. B. Nicholson, made similar observations, and especially were astonished about the high moduli of heavy bars.

General Morin says: "The softest and most ductile iron furnishes values as low as 21,300,000, and even 17,000,000 lbs. But it is known to all practical iron men that the Swedes iron is the very softest, and is the most ductile iron in the world (fine wire, No. 50, drawn from it), and yet its modulus by Styffe was not found 21 or 17 millions, but between $27\frac{1}{2}$ and $34\frac{1}{2}$ millions."

The bars used for the Vienna Railroad Suspension Bridge (certainly of excellent make and stock) are reported to have differed remarkably, and so much so that bars of nearly equal moduli were put into the same panels of the chains.

Mr. B. Baker, of London, says: "Every practical man, who has noted the behavior of iron girders under bending stresses, knows that whilst one girder may deflect a certain amount under the test, another one *precisely similar*, and placed *apparently* under the *same* condition, deflects some *thirty per cent. more* or *less*."

Redtenbacher, who is known to be a conscientious and learned author, quotes the moduli of iron from 21,300,000 to 35,500,000 pounds, of steel from 28,500,000 to 34,100,000.

Reuleaux (Der Constructeur) for wire, bars, and ordinary steel gives 28,500,000, for cast-steel gives 42,700,000 pounds.

Kupffer, in St. Petersburg, by experiments on sound and flexure gets from 25,000,000 to 30,000,000 pounds.

Coulomb, Tredgold, Lagerhjielm and Woehler found the modulus of hardened steel exactly equal to that of unhardened steel; Kupffer, in some instances, finds the modulus of hardened steel $6\frac{1}{2}$ per cent. higher.

Styffe says that the modulus of cold worked iron is low, but can be raised by a glowing heat. He also says that the presence of phosphorus influences the modulus. There are thus great differences of opinion. But so much is cercain that these experiments prove that Morin's hypothesis cannot be sustained,

the moduli of iron of the *same stock and make* varying considerably.

The fact is that, in order to get a proper idea of the moduli of bridge members, it is indispensable to test such pieces as *actually are used in bridges.* This, for tensile members, Malberg, Bauschinger and myself have done, whilst Mr. Th. Lovett's results for the first time refer to the moduli of compression members, such as actually are used in bridges.

General Morin's generalization being inconsistent in itself (he puts the most ductile and the best charcoal irons in the two extremest classes, whilst the best charcoal irons are *also* the most ductile and the softest brands), and *all* experimenter's results agreeing as to great variability of moduli; the young instructor must see that he is rather in position to learn than to teach.

I have expressly stated in my article on Continuous Bridges that the many thousand bars tested by me were "double refined (best-best) Phœnix bars" for use in bridges, and it is certainly not my fault if our instructor asks what kind of iron was experimented upon. The conclusion then is this: *The hypothesis of a constant modulus of elasticity is not supported by experiments*, and *consequently cannot* be made *until a method is found* by which to secure iron of equal moduli *without extra cost.* The price of double refined iron is about twenty per cent. higher than that of single refined iron, and double refined iron is only used in the tensile, (eye-bars and diagonal rods), but not in the other members of first-class bridges. During the first four years of my presence in this country, I have devoted much time to the further study of the theory of continuous girders. In 1867, I have investigated the question whether it would not be possible to reduce the moments of flexure, caused by moving loads, of such bridges by interposing systems of springs between the trusses and their supports. This method, by *adjustment* of the springs (acting as huge dynamometers, previously tested), I hoped to use also towards regulating the reactions of the piers and herewith the strains; in other words, I intended to use these systems of springs as elastic scales. The calculations connected therewith were of a rather complicated character, and proved that the advantages of the system were neutralized by the expense of the springs. Later I tried (see foot-notes of my article) to substitute for these springs cheap scales, designed on the principle of the lever, the power for raising the trusses being furnished by hydraulic rams. I further continued these investigations by making entirely new formulae, involving a great amount of mathematical labor, which formulae contained the influence on the deflections, &c., of *not only* the chords, but of each separate chord member, and also of *each web member*, and I had the hope that, by these improvements in theory, and by the others regarding corrections of irregularities of execution, I might become successful in arranging pinjointed continuous girders for the use in this country of pushing, without scaffolds, bridges of large spans over the piers. I also hoped to save material. But I found myself *compelled* to give up the hope of presenting something better than we have, since I had learned to appreciate the great advantages as regards economy of the American single span bridges, and more especially when I noticed, to my disappointment, the great and thus far unaccountable variations in the moduli of *best-best* bars of the *same stock and same manufacture*, excluding under all circumstances the supposition of a constant value of modulus. The reason, therefore, that I have abandoned continuous bridges is not that I have not sufficiently studied their mathematical relations, for this I have done thoroughly for a period of four years, my position in 1867 being in advance of that of our instructor in 1876, but it is this: that, after a *conscientious* weighing of *all elements*, I could not help admitting that continuous girders are inferior to single spans in *every* respect. The difficulty of making calculations of continuous girders, however, is the last and lightest objection, for every average polytechnic scholar can do this algebraic drudgery, involving little or no thought, but only a sufficient volume of Chinese patience.

I blame the author for making, as regards my personal opinions, quite a series of statements deficient in truth.

I do *not* advise "to abandon the the-

ory of flexure," and therefore I am *not* inconsistent if I apply it towards calculating the moduli from experiments on flexure. There is no passage of this kind in any of the papers written by me. On the contrary, I have shown conclusively, and have given expression on pages 21 and 40 of "Van Nostrand's Science Series No. 4," that the theory of flexure given by Euler, of Basil, in the year 1744, improperly ascribed to Navier, agrees wonderfully well with experiments for strains below what is called the elastic limit of cylindrical solid sections of *first-class homogeneous iron or steel*, and I have expressed this view again on page 198, of my article on Continuous Girders, Vol. V, Transactions Am. Soc. Civ. Engrs.

In other words, whilst I approve of the *proper* use of this theory, I do not approve of its misapplication. A continuous bridge is not simply a cylindrical, solid, homogeneous beam. It is composed of many parts of unequal moduli, sections and strength, and it cannot be considered as a unit. And there's the rub, that beginners in mathematics but too often apply theories, no matter whether their suppositions agree with the physical conditions of the object or not. They imagine that, because a mathematical expression is true, any subject into which they can throw a few formulae, thereby *ipso facto* must participate of that truth.

All that I have done was to prove that practical bridgemen, who have not yet studied deeply the subject of continuous bridges, need not regard them seriously, the fact being, that progress also in bridge building can not be separated from simplicity.

And this, my conclusion, is justified, because these structures are *not any more, and even less, economical* as regards *quantity of material*, and in regard to *quality are decidedly inferior* to single-span bridges of proper proportions and details.

There is no continuous bridge in the world which I know to be lighter than we can build equally strong single spans. If the instructor of New Haven knows of one single executed continuous bridge that is lighter, let him give us the particulars thereof, or, if he can design one, let him give us *working drawings* and *computation* that *we* may be *able* to calculate precisely the quantities ourselves, and to see whether such a bridge is properly designed, and whether it is lighter than we can design bridges, whose calculation is only based on the plain law of the lever. Since he recommends continuous bridges, it is *his business* to also give us *proof* of their superiority as *practical structures*, for his claims for saving of 36 per cent., 20 and 40 per cent., I consider entirely visionary. I suggest the author will calculate and give us the exact figures, dimensions and drawings of a single track railroad bridge of 1,000 feet length, continuous over three openings, calculated to carry a live load of 2,240 lbs. per foot, headed by a locomotive concentrating 80,000 lbs. upon a 12-feet wheel base. The bridge to have iron stringers, and to be not strained over 10,000 lbs. per square inch in any member or detail. The compressional members to be proportioned by Rankine's formula, the least radius of gyration being considered, and 10,000 lbs. per square inch being the basis strain. As soon as the author has given us the necessary documents from which to judge his capacity for designing a bridge of this kind, I also will give my complete figures and data on single spans for the same bridge. I have calculated towards my own information two continuous railroad spans of 200 feet, as compared with two single spans. Both designs had 12 panels per span, both were quadrangular trusses with vertical end posts, both were calculated for a dead load of 1,200 lbs. per foot, and for a live load of 2,240 lbs., headed by a locomotive concentrating on a crossbearer 62,000 lbs. I also have calculated, under the same suppositions, three continuous spans of 183′ 4″, 233′ 4″, and 183′ 4″ spans, 25′ deep. Each of the three designs was calculated for *its own* (*nearly most*) *economical height of truss*, but not by considering all of the same height, regardless of economy. There are in the first place the

(*See Table on following page.*)

By making the single spans with inclined end-posts a further saving of material and labor can be secured. The figures prove that there even is *no theoretical* saving in these continuous bridges,

THEORETICAL QUANTITIES.

	Pound, Feet.	Total.	Weight per lin. ft. of trusses only.	
			Lbs.	Per cent.
Single Spans.....Chords	837,670	1,555,340	519	100
27′ deep (not deep enough).....Webs	718,670			
Two continuous spans.....Chords	790,500	1,563,330	521	100.5
25′ deep.....Webs	772,830			
Three continuous spans.....Chords	819,000	1,708,000	570	109.7
25′ deep (a little too deep).....Webs	889,000			

(N. B.—In the three continuous spans the effect of the heavy locomotive is not yet considered.)

and practically, as we shall see, they stand behind entirely.

It might be rejoined that the advantages of continuity better present themselves in case of heavier dead loads. Therefore, under precisely the same conditions, but for a dead load of 2,400 lbs. I have calculated also two single spans, and three continuous spans. These are the

THEORETICAL QUANTITIES.

	Pound, Feet.	Total.	Weight per foot of trusses.	
			Lbs.	Per cent.
Single Spans, 200′, 27′ deep.....Chords	1,130,000	2,045,000	682	101.4
Locomotive considered, ...Webs	915,000			
Three continuous spans, 25′ deep.....Chords	958,400	2,016,600	672	100.0
Locomotive *not* considered, ...Webs	1,058,200			

In this instance the continuous girders are designed too deep, and the single spans too shallow, for their proper heights the quantities of the chords should have become nearly equal to those in the webs; and by also considering the locomotive load the theoretical advantage of 1.4 per cent. would have been turned the other way.

In all these examples, the *chords* of the continuous girders can be noticed to be *lighter* than those of single spans, whilst, reversedly, the *webs* of continuous girder are *heavier* than those of single spans, in such proportions that the *gain in the chords is just about neutralized by the loss in the webs.*

It must be expressly stated that, if it were possible with continuous girders to save so much in the chords, that this saving, less the extra weight in the webs, would leave a final saving; this would *only* indicate a saving in the theoretical value of the trusses. The connecting parts, as latticing, rivets, reinforcing plates, then the lateral strutting, lateral diagonals, and the whole floors remain constant quantities unaltered by the principle of continuity. In our example, about one-third of the iron of the whole bridge is a constant quantity, and a theoretical saving in the trusses of three per cent. could only realize two per cent. on the iron work of the whole bridge. Most of the enthusiastic writers on continuity, however, only mention the *theoretical* saving in the *chords*, without subtracting the loss in webs, or without considering the quantity of constant weight of iron.

While acknowledged standard writers, as Laisle and Schubler, say, that "*by*

the continuity, which is about as economical for two as for three openings, a saving in the weight of the chords of from fifteen to twenty per cent. can be obtained." (Page 135, Laisle and Schubler, der Ban der Brucken trager, 1864) : our instructor is sanguine enough to claim for the *whole bridge* a "saving of iron, amounting from twenty to forty per cent. over the ordinary construction of single spans."

His authority, the Professor Winkler, of Vienna, says, that more than four spans should not be made continuous, and that the economy by continuity for four spans is about as great as for three spans, and since Laisle and Schubler declare that two spans give about as much economy as three; we would have to conclude that the *number* of spans is immaterial in continuous girders, as far as economy in the chords is concerned.

Winkler gives the following comparison of single span trusses with parallel chords and continuous girders (of three openings):

PRACTICAL VALUES OF TRUSSES ONLY.

33′	Single	Spans,	100	Continuous	Spans,	96
164′	"	"	100	"	"	89
328′	"	"	100	"	"	78
492′	"	"	100	"	"	73

This amounts to from four to twenty-seven per cent. in the *trusses only*, whilst the author has from twenty to forty per cent. in the whole bridge (so at least it must be assumed, for he has not made any provisional remark, and therefore so it would be understood by those not entering any more deeply into the question than he has done).

However, it must be expressly remarked that Herr Winkler, at the time he wrote his book, was not so far advanced as to realize that single span bridges *must* be built *deeper* than continuous bridges, or that these *must* be built *shallower* than those; and he compares both kinds of trusses for the same depth, this being undoubtedly wrong. Had he considered this fact, which, however he has done in a similar comparison (parallel chords and curved chords), and had he also considered the additional material needed in the regions of continuous bridges, where the same members, have to carry tension as well as pressure also he would have found that up to at least four hundred feet spans there is no economy from the principle of continuity.

I now shall give the practical weights calculated for single and for continuous spans, the *same* details being used (expressly stated so in my paper, but untruly contradicted by Mr. Merriman):

Two continuous spans, total weight per foot,	1,466 lbs.
Two single spans, same details, per ft.	1,383 "
" " " " except Phœnix columns instead of open posts, per foot,	1,337 "

These weights include the floor timber and nails, 300 lbs. per ft., and the *constant* quantities of iron in floor connections, &c., of 298 lbs. per foot.

Only for very large spans with *limited depths* there would be a theoretical advantage in the principle of continuity, when it would become desirable to build such bridges with hinges in alternate spans. That there *is no advance* in bridge building in connection with the ordinary continuous girders, can be brought home to Mr. Merriman also in this way:

We use for this purpose again *his* own authority, the Professor Dr. Winkler of Vienna. Though I do not concur with this gentleman in a good many respects, yet his conclusion that up to spans of 492 feet length *Schwedler* trusses, from 6 to 0 per cent. are *lighter* than continuous trusses (see page 15 of second part of his book, Vienna, 1872,) seems to be quite reasonable. Winkler calculates these trusses for five-fourths the depths of continuous girders which is scientifically correct.

But he cannot practically build them any higher than we build our Whipple trusses, with inclined endposts, and with our improved, very easily variable, chord and web members.

Hence we have in the first place a proof given by a theorist of the purest water, and "*by the writer's own authority*," that there are certain single-span trusses lighter than continuous trusses. But it also can be proved that with our details we can build the single span Whipple trusses just as deep as it is possible to build Schwedler trusses, with partly curved and in the center parallel chords, which, in fact, constitute only an approach from parabolic trusses to the simplest and best form, namely, the trapezoidal

truss. We can prove that these trusses are just as light theoretically and practically as Schwedler trusses, and I am confident for large spans they will be remarkably more economical. (Compare K. Culman's Die Graphische Static, Zurich, 1866, page 535, the last 11 lines below, and page 536, 6 lines from above.

Hence we also have an indirect proof, furnished by the writer's own authority, that the present American practice, both on account of its economy in material and as regards workmanship, is ahead of the system which he not very successfully wishes to introduce.

Again, Herr Schwedler, who is the government examiner of all new bridge designs in the Prussian Kingdom, builds *no* continuous fixed girders, which he *expressly* and *decidedly* has abandoned since 1865, (see his theses on bridge-building, Erbkam's Zeitschrift fur Banwesen, Berlin, 1865.) But Herr Schwedler, being an engineer of high position who has very essentially promoted the theory of strains in bridges, domes, &c., and who is the originator of the truss known by his name, and of an ingenious and successful system of pivot tables for draw bridges, has built a great many bridges in Prussia. He, therefore, is theoretically as well as practically very high authority, and certainly has his *good reasons* for rejecting the theory of continuity.

In France there are a few iron works who build continuous bridges in preference to others because it is in their *interest* to push the girders over the piers, for which operation they are prepared, their plant being capable of being used over and over again. The work, of course, thereby is not secured to be as reliable as if erected on carefully built false works.

Two of the German Commissioners to the Philadelphia Exhibition, both Prussian government engineers of scientific education, have informed me that the erection of continuous girders in Germany has ended, and indeed I know of no important structure of this kind that has been built there since the last five years.

Professor Paul Panayeff, of the Imperial Technical School of Moscow, Commissioner to the Exhibition, a gentleman whom I found to possess much practical and theoretical knowledge, and to be a warm admirer of American engineering practice, and especially bridge building, informs me that since three years no more continuous bridges were built in Russia, the deficiencies of the theory and their practical difficulties of execution and working being recognized.

Professor Heintzerburg, of the Prussian Polytechnic School of Aix-la-Chapelle, whom I know since 26 years, with whom I correspond, and whose work by Mr. Merriman is *recommended in very flattering terms*, in the chapter treating on the systems of bridges of the future, has made the following remark in the year 1870:

On account of the *great statical sensitiveness of continuous bridges* as regards inexact execution or change of the heights of support after some time, or in reference to settling of masonry or sinking of piers, those constructions *resting on two supports only* (which include single spans and continuous bridges with hinges) *doing away with that sensitiveness, are more and more preferred.*

As regards the substructures, it is acknowledged that single span bridges can be placed on masonry of a more economical class than those for continuous bridges. The foundations and masonry of continuous bridges must not settle at all; those for single spans may settle several inches without interfering with the office of the bridge. The piers for single spans are practically good enough if their foundations and masonry are sufficiently strong to resist water and ice, and if they can securely carry the load. Therefore a *cheaper* class of masonry may be chosen and the pressure per square foot on the foundation may be taken higher than would be necessary for foundations intended to carry continuous bridges.

It, therefore, is selfevident that in many instances the adoption of these bridges would compel to more rigid specifications as to foundations and masonry than would be necessary for piers of single span bridges. In many instances proper stone would have to be got from large distances. The use of cribwork as foundation would have to be dispensed with altogether, &c., &c.

Now this being quite clear to every practical man, what are we to think of

our instructor's conclusion No. 3, of the alleged advantages for continuous girders?

He claims:

3. Saving in material for the piers since a *less bearing surface* is required than for two ends of single span bridges.

But it is known that the middle piers of continuous bridges receive *greater pressures* than the piers of single spans. Further, only a pressure of so and so many lbs. per square inch on the masonry, transferred by the bedplates, is admissible, which for very good stone is about 300 lbs. per square inch, and for a low class of masonry was found to be too high at 150 lbs. per square inch. The bedplates, then, for *continuous bridges* must become *larger*, for the *pressure is larger;* further, it being so very important that the piers do not settle in part, the *pressure per square inch* must be taken *less* than that for single span bridges. If it were possible to reduce the width of piers below what it usually is, there would be no difficulty in making the bedplates more broad than long, and of reducing their length considerably. Exclusively practical considerations limit the width of a pier.

That special caution in the construction of foundations and masonry of continuous bridges are required the fall in this year of the Riesa bridge, caused by undermined masonry, in Saxony, built 1867, gives testimony.*

Likewise the settling of center piers of continuous draw bridges happens not unfrequently. A bridge of this kind near New Haven was commenced two years ago, but is not yet in operation. The round pier of this bridge tipped and the draw could not be turned.

The superstructure had to be jacked up, the masonry had to be removed partly and then had to be newly laid. Similar irregularities have happened elsewhere and *were noticed because* of the irregularities caused thereby of the revolving superstructure. Of single span bridges these irregularities are hardly ever noticed from the reason that they do not influence noticeably the value of these bridges.

On page 189 of the Transactions of the Society Civil Engineers I have shown that because we *must* construct continuous girders *shallower* than single spans the deflections of both designs do *become equal.* Knowing that there are theorists so filled with the conscientiousness of their value that they bring arguments in favor of continuous bridges on the score of smaller deflections, involving contempt for the common sense of the members of the profession, I have expressly stated that there would be no interest felt for these latter designs even if their deflections were fifty per cent. less than those of single spans.

Also, our instructor's authority, the Professor Winkler, concurs in this regard and (page 5, part 2) "places no particular importance" on this point. Indeed there is *not the slightest want* for reduction of deflections of *our bridges*, which are fully stiff enough. A certain elasticity, on the contrary, might be not undesirable. But considering that one of our theorists could take up this irrelevant question again, in No. 15 of my conclusions, I have repeated that there is no difference in the deflections of properly designed single spans as compared with those of continuous bridges, (these deflections being calculated by the imperfect common theory, not considering the webs.) But our instructor remarks that this is a fact known to every schoolboy. Why, then, is it that he does not understand this question and still claims, under No. 1, as an advantage, greater stiffness for continuous bridges?

Our instructor seems to have no proper definition for what a continuous truss is. This is the definition:

A continuous truss is a beam which is composed of more than one span, the reactions of the piers being only vertical and the strains in one span being influenced by the weights on the others.

Commonly, where no distinction is made, by "continuous girders" are meant those without hinges.

* Consisting of a span of 92 meters and 4 continuous spans of 30 meters, railroad and roadway bridges side by side. The falling of a portion of the pier made the roadway bridge of 92 meters fall into the river, which being a riveted structure with wooden floor caused the water to form a fall over a weir and to undermine the other pier, whose total fall caused the continuous bridge to break right off at the next pier. A small portion of the iron work remaining on the piers, the rest formed a tangled mass of distorted riveted work. Had there been only single spans, with American details, not only the greater part of the bridge would have been saved from falling, but the fallen parts very easily could have been repaired to be used over again. Similar instances happen not unfrequently in this country where scaffolds by freshets, ice or heavy gales of wind are thrown in the river, whereupon the iron parts are picked up, repaired and put in place.

Continuous girders with hinges in alternate spans were patented by Gerber (in Bavaria, December, 1866,) and they were invented independently by myself early in 1867 in *this* country, proof of which fact can be given if desired. Since I have shown that I do not reject the theory of flexure of beams if applied where it *can be* applied, I do not consider it worth while to further dwell on the author's numerous incorrect statements, nor on the erroneous and unscientific conclusions therefrom derived.

I only will still show that he makes another fundamental "faux pas" in *theory* on page 158 of the August number of the magazine.

I shall prove that:

If according to the theory the *properly calculated* deflections of continuous girders do *not* agree with the *actual* deflections, this is an indication that either the theory used is imperfect, or that the manufacture does not answer the suppositions; at all events that the *strains* are *not those* for which the members of the bridge were proportioned.

Of course the expression of *properly calculated* deflections means that *at least* the average modulus of elasticity of the material has been used in the calculation.

In the main building of the Philadelphia Exhibition the North Eastern R. R. of Switzerland has laid out a report on their bridges.*

One of the continuous structures of the North Eastern R. R. (which is considerably heavier than we build equally strong and equally long single spans) is the *Ergolz Bridge*, near Augst, consisting of four spans of 100, 122, 122 and 100 feet, 11′ 2″ deep.

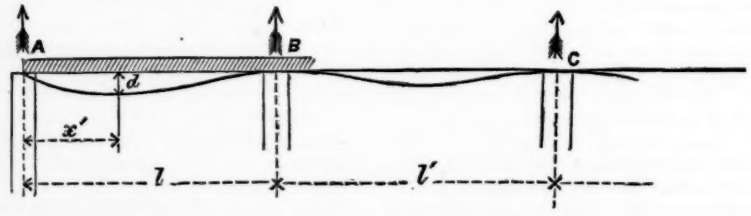
The test-load of this bridge consisted of locomotives 2,667 pounds per foot. The theoretical maxima deflections (the moduli I learn to have been experimented upon, but to what extent is not known) were:

14, 19, 19 and 14 millimeters ($1^{\text{mm}} = \frac{1}{25}''$).

The actual maxima deflections under strains of mean velocity were:

11, 10, 11, 12 millimeters.

The calculation hence was out of the way by as much as 90 per cent. to, in the minimum, 17 per cent. If *all* actual deflections had been less in the *same proportion*, the result might have been *attributed to the modulus* being so much larger than calculated upon. But this supposition is here inadmissible, and we must under any circumstances prove our proposition and Mr. Merriman's error on *his own premises*. We must assume the modulus to be a constant value in the following very elementary, algebraical deduction:



Let A B C represent a continuous bridge, A and B, &c., representing reactions under uniform load on one or more spans.

l denotes the length of span A B.

* This official report is interesting in many ways. One remark thereof is: "*The erection of ironwork on scaffolds is preferred to the method of pushing the girders over the piers. This latter method never is allowed without intermediate temporary supports, and without reinforcement* (Armirung) *of the girders.*"

The acknowledged best builder in Switzerland always uses false works, but the mentioned French works push their continuous girders over the piers. However, it was observed that they thereby were likely to furnish second class work, and it happened that the violence, or the undue strains, connected with this method, caused rivet heads to fall off.

In case the method of pushing continuous girders over the piers is not to be used, their erection becomes *more* expensive than that of single spans. Not only that these scaffolds must be very unyielding and substantial, but *all spans* of the same set of continuous girders must be provided with false works at the same time, whereas, in the erection of single spans, only a scaffold for *one span* is used, or is usually used repeatedly. Also the risk, by erecting two or three spans at the same time, is considerably increased. The economical method of pushing girders over piers in a few rare instances, and under proper precautions (I learn it was proposed for the Kentucky River Bridge, Cin. S. R. R.), might be used when the girders finally could be separated again by establishing hinges in alternate spans.

x_2 denotes an abscissis for which the theoretical deflection is d, and this

x_1 denotes an abscissis for which the actual deflection is d_1.

A denotes the theoretical reaction at A.

A_1 denotes the actual reaction at A.

p in the load per foot on A B being fully loaded.

E is the assumed constant modulus of elasticity.

I is constant moment of inertia of the bridge.

We have the well known equation:

$$EI\frac{dy}{dx}=A.\frac{x^2}{2}-p.\frac{x^3}{6}+(\text{constant}=C)$$

and

$$EIy=\frac{A}{6}.(x^3-l^2x)-\frac{p}{24}(x^4-l^2x)$$

because:

for $x=l$, $y=o$, and $C=-\left(A.\frac{l^2}{6}-\frac{p}{24}.l^3\right)$

We now can calculate the deflection d for a point whose abscissis $=x_1$.

Theoretically we ought to get:

$$E.I.d=\frac{A}{6}(x_1^3-l^2x_1)-\frac{p}{24}(x_1^4-l^2x_1)$$

but practically we do receive:

$$E.I.d_1=\frac{A_1}{6}(x_1^3-l^2x_1)-\frac{p}{24}(x_1^4-l^2x_1)$$

Now: E, I, x_1, l and p *being constant* quantities, A_1 cannot be equal to A, because d_1 is not equal to d. They only could become equal if E were different from what it has been supposed in the calculation. This supposition here falls away, because the actual deflections of the Augst Bridge do *not* correspond *proportionally* with the theoretical ones. Hence, by subtracting the two equations, we get:

$$EI(d-d_1)=\frac{A-A_1}{6}(x_1^3-l^2x_1)$$

in words:

The difference of actual and theoretical deflection would be proportional to the difference of actual and theoretical reaction, provided we were right in using the theory in the calculation of continuous trusses. And we find:

$$A_1=A+\frac{d_1-d}{(x_1^3-l^2x)}.6.E.I.$$

The actual reaction is greater than the theoretical reaction by

$$\frac{d_1-d}{x_1^3-l^2x}.6.EI, \text{ or consequently;}$$

The actual reaction not being equal to the theoretical one, the actual strains are not the theoretical ones, or the calculation of theory does not correspond with reality.

Whether this proves incorrectness of the theory, or improper execution, is not open to a conclusion from the mere experimental results without the values E and I. But it is sufficient to know that remarkable differences of theory and practice do exist, and may be expected again.

That the ordinary theory is imperfect, on account also of the web not being considered in the development of the deflections, has been proved by me, and it has been shown that this abbreviation of theory may lead to errors as large as thirty-six per cent. of calculated angles of deflection (see page 198 of Transactions). The above investigation may be extended, and it also can be proved that, founding on the ordinary theory, the difference of actual and calculated reactions over middle pier B must be proportional to the difference of actual and calculated deflections, but if $A_1>A$, there must be $B_1<B$.

Our instructor, however, makes still another entirely untrue statement, namely, that I assert that the actual strains are to the theoretical ones as the actual deflections are to the calculated ones. He must also correct this gross misstatement. Founding thereon he had the kindness to remark:

"This (my just proved mathematical conclusions) we can only regard as a striking instance of the incompetency of practical men to draw conclusions from even simple experiments."

Quite a number of similar assertions and of equal value can be found in the second part of his paper.* There he

* Some of these assertions and mistakes are answered this way: ad. 4. Our instructor has not yet comprehended that, while it is possible to build single span bridges with two or more systems of diagonals, *each independent of the other*, this independence *cannot be obtained at all in case of continuous bridges with more than one system of webbing*. Consequently, the first can and the *latter can not* be calculated.

Ad. 6. None but superficial theorists assert that the *correct application* of the principle of continuity is not an exceedingly tedious labor.

Ad. 7. Woehler's experiments are confirmed by Prof.

(September edition of the Magazine) has quoted in part my conclusions as to continuous girders. But he has not quoted them, as they originally are, but he has cut them down, has distorted and arranged the same in such a manner as to frequently, and I fear intentionally, hide their entire meaning.

Those readers who take an interest in the question will please read and compare the original, when they will find to what practice this gentleman is reduced towards defending a compilation, which is intended to be his scientific debut. Nor will I repeat the algebraic proof (see my paper), that also his conclusions (11 and 12) as regards extra strains in continuous girders not fitting their bed-plate heights, or in case one chord is protected from the heat of the sun, give another testimony of his immatured understanding of even the *principle* of continuity. Mere common sense is sufficient to condemn his conclusions on these questions. It may be that Mr. Merriman has been a very industrious Polytechnic student, but the fact is, that as soon as he leaves the common road, paved with the myriad of books and articles on continuity, from which he simply has compiled the non-personal part of his paper, he is no more at home, he having proved himself to be unprepared to make independent analytical investigations.

In order to be prepared to recommend an alleged improvement, or to introduce a novel design from one country into another, it is necessary to first *learn* to *appreciate what there is*, to see the *good reasons why* a construction is used in preference of another, what local influences, as prices of skilled or unskilled labor, of the several classes of iron, of wood, masonry, climate, &c., modify the style of design.

Nor is the theory of continuity anything new in this country. The inventor, Colonel Long, in his once famous book (edited already, 1841) has treated this question, and numbers of wooden continuous bridges formerly were built in this country, a construction which, at that time and for this material, was noticeably more in place than is, to-day, the recommendation of continuous skeleton structures of wrought-iron.

Nor must the young instructor think that there are not a great number of scientific men connected with our large bridge firms, who long ago would have introduced wrought-iron continuous bridges, had they been able to see any economy in them. Thus, Mr. Shaler Smith has told me (about four years ago) that, for a certain great project, he has made careful estimates on 500′ span continuous bridges, but that he found them to be so heavy in their webs as to annihilate their advantages in the chords, which is precisely the same conclusion at which I have arrived. Hardly anybody can appreciate mathematical sciences higher than myself, but I do not approve of their *abuse*, nor do I wish to underrate practice. It is a fact that arts are considerably promoted by harmonious action of theory and practice, but so that, if a man lacks somewhat in one of these elements, it is less objectionable if the deficiency is on the theoretical side.

Continuous girders *have had* their *legitimate time*, and this time was, when *large plate girders* were built, whose webs—being sufficiently strong to carry the increased strains of continuous girders—were *too thin* already to suffer a further reduction of weight. Any saving in the chords of these shallow plate girders, the theory being accepted, was so much gain.

But since we now build skeleton structures of which we can *almost theoretically* adapt the web members to their strains, further, since we have better details to our disposition than we had at the time when the once justly famous tubular and plate girders were erected in England and in France, and especially as it is *scientifically wrong* to apply the ordinary theory of *solid homogeneous* beams to the *compound* designs of skeleton structures of *great depth*; the reasons for erecting continuous girders have vanished, they being neither economical nor scientific.

Actually, American practical bridge

Spangenberg, of Berlin, but having been, perhaps, the most thorough experiments ever made, and having occupied over twelve years' time, they did not need this confirmation. Also, compare Inspecting Engineer Muller's article in the "Zeitschrift des Ostreichischen Ingenieur und Architecten Vereins," 1873.

Ad. 8. This shows the poverty of the instructor in practical matters, and needs no further comment.

Ad. 14. I *have* compared single and continuous spans of 200 feet for the *same* details, and again also for these details, only replacing open latticed posts by Phoenix columns. The Dirschau Bridge consists of three pair of continuous spans, it is not continuous over six spans (see "Heintzerling," page 273).

building of good firms is the most scientific in the world, and is ahead of the speculations of purely mathematical theorists. It can dispense with advice from this party; for by development and invention of much stronger and much more economical details and connections they have brought the actual quantities very near to the theoretical ones, whereby they have been able to build *correctly executed deep* trusses without almost incurring any loss of material at the ends of the chords or in the centers of the webs.

Improvements in bridge-building are aimed at by me as well as by any bridge engineer, and these improvements must be suggested by the results of experiments furnishing new physical and new practical data from which to derive new deductions. Further mathematical deductions from old experiments, according to my opinion, having ceased or having nearly ceased to be valuable to bridge building, we need now experiments on the proper proportions and strength of eye bars of different makes, of compression members, beams, pins, rivets, &c., and their connections, and more especially we much need exact figures on the *durability of these elements and of their combinations by testing them under repeated strains such as are sustained by our structures every day.*

ON AN INTEGRATING MACHINE HAVING A NEW KINEMATIC PRINCIPLE.

By Professor JAMES THOMSON, LL.D., F.R.S.E.

Proceedings of the Royal Society.

The kinematic principle for integrating ydx, which is used in the instruments well known as Morin's Dynamometer* and Sang's Planimeter, admirable as it is in many respects, involves one element of imperfection which cannot but prevent our contemplating it with full satisfaction. This imperfection consists in the sliding action which the edge wheel or roller is required to take in conjunction with its rolling action, which alone is desirable for exact communication of motion from the disk or cone to the edge roller.

The very ingenious, simple, and practically useful instrument well known as Amsler's Polar Planimeter, although different in its main features of principle and mode of action from the instruments just referred to, ranks along with them in involving the like imperfection of requiring to have a sidewise sliding action of its edge rolling wheel, besides the desirable rolling action on the surface which imparts to it its revolving motion—a surface which in this case is not a disk or cone, but is the surface of the paper, or any other plane face, on which the map or other plane diagram to be evaluated in area is drawn.

Professor J. Clerk Maxwell, having seen Sang's Planimeter in the Great Exhibition of 1851, and having become convinced that the combination of slipping and rolling was a drawback on the perfection of the instrument, began to search for some arrangement by which the motion should be that of perfect rolling in every action of the instrument, corresponding to that of combined slipping and rolling in previous instruments. He succeeded in devising a new form of planimeter or integrating machine with a quite new and very beautiful principle of kinematic action depending on the mutual rolling of two equal spheres, each on the other. He described this in a paper submitted to the Royal Scottish Society of Arts in January, 1855, which is published in vol. iv. of the Transactions of that Society. In that paper he

* Instruments of this kind, and any others for measuring mechanical work, may better in future be called Ergometers than Dynamometers. The name "dynamometer" has been and continues to be in common use for signifying a spring instrument for measuring *forces;* but an instrument for measuring *work*, being distinct in its nature and object, ought to have a different and more suitable designation. The name "dynamometer," besides, appears to be badly formed from the Greek, and for designating an instrument for *measurement of force*, I would suggest that the name may with advantage be changed to *dynamímeter*.

also offered a suggestion, which appears to be both interesting and important, proposing the attainment of the desired conditions of action by the mutual rolling of a cone and cylinder with their axes at right angles.

The idea of using pure rolling instead of combined rolling and slipping was communicated to me by Professor Maxwell, when I had the pleasure of learning from himself some particulars as to the nature of his contrivance. Afterwards (some time between the years 1861 and 1864), while endeavoring to contrive means for the attainment in meteorological observatories of certain integrations in respect to the motions of the wind, and also in endeavoring to devise a planimeter more satisfactory in principle than either Sang's or Amsler's planimeter (even though, on grounds of practical simplicity and convenience, unlikely to turn out preferable to Amsler's in ordinary cases of taking areas from maps or other diagrams, but something that I hoped might possibly be attainable which, while having the merit of working by pure rolling contact, might be simpler than the instrument of Professor Maxwell and preferable to it in mechanism), I succeeded in devising for the desired object a new kinematic method, which has ever since appeared to me likely sometime to prove valuable when occasion for its employment might be found. Now, within the last few days, this principle, on being suggested to my brother as perhaps capable of being usefully employed towards the development of tide-calculating machines which he had been devising, has been found by him to be capable of being introduced and combined in several ways to produce important results. On his advice, therefore, I now offer to the Royal Society a brief description of the new principle as devised by me.

The new principle consists primarily in the transmission of motion from a disk or cone to a cylinder by the intervention of a loose ball, which presses by its gravity on the disk and cylinder, or on the cone and cylinder, as the case may be, the pressure being sufficient to give the necessary frictional coherence at each point of rolling contact; and the axis of the disk or cone and that of the cylinder being both held fixed in position by bearings in stationary framework, and the arrangement of these axes being such that when the disk or the cone and the cylinder are kept steady, or, in other words, without rotation on their axes, the ball can roll along them in contact with both, so that the point of rolling contact between the ball and the cylinder shall traverse a straight line on the cylindric surface parallel necessarily to the axis of the cylinder—and so that, in the case of a disk being used, the point of rolling contact of the ball with the disk shall traverse a straight line passing through the center of the disk—or that, in case of a cone being used, the line of rolling contact of the ball on the cone shall traverse a straight line on the conical surface, directed necessarily towards the vertex of the cone. It will thus readily be seen that, whether the cylinder and the disk or cone be at rest or revolving on their axes, the two lines of rolling contact of the ball, one on the cylindric surface and the other on the disk or cone, when both considered as lines traced out in space fixed relatively to the framing of the whole instrument, will be two parallel straight lines, and that the line of motion of the ball's center will be straight and parallel to them. For facilitating explanations, the motion of the center of the ball along its path parallel to the axis of the cylinder may be called the ball's longitudinal motion.

Now for the integration of ydx: the distance of the point of contact of the ball with the disk or cone from the center of the disk or vertex of the cone in the ball's longitudinal motion is to represent y, while the angular space turned by the disk or cone from any initial position represents x; and then the angular space turned by the cylinder will, when multiplied by a suitable constant numerical coefficient, express the integral in terms of any required unit for its evaluation.

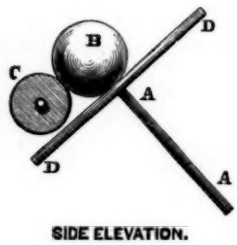
The longitudinal motion may be imparted to the ball by having the framing of the whole instrument so placed that the lines of longitudinal motion of the two points of contact and of the ball's center, which are three straight lines mutually parallel, shall be inclined to the horizontal sufficiently to make the ball tend decidedly to descend along the

line of its longitudinal motion, and then regulating its motion by an abutting controller, which may have at its point of contact, where it presses on the ball, a plane face perpendicular to the line of the ball's motion. Otherwise the longitudinal motion may, for some cases, preferably be imparted to the ball by having the direction of that motion horizontal, and having two controlling flat faces acting in close contact without tightness at opposite extremities of the ball's diameter, which at any moment is in the line of the ball's motion or is parallel to the axis of the cylinder.

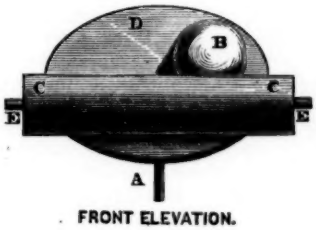
It is worthy of notice that, in the case of the disk, ball, and cylinder integrator, no theoretical nor important practical fault in the action of the instrument would be involved in any deficiency of perfect exactitude in the practical accomplishment of the desired condition that the line of motion of the ball's point of contact with the disk should pass through the center of the disk. The reason of this will be obvious enough on a little consideration.

The plane of the disk may suitably be placed inclined to the horizontal at some such angle as 45°; and the accompanying sketch, together with the model, which will be submitted to the Society by my brother, will aid towards the clear understanding of the explanations which have been given.

My brother has pointed out to me that an additional operation, important for some purposes, may be effected by arranging that the machine shall give a continuous record of the growth of the integral by introducing additional mechanism suitable for continually describing a curve such that for each point of it the abscissa shall represent the value of x, and the ordinate shall represent the integral attained from $x=0$ forward to that value of x. This, he has pointed out, may be effected in practice by having a cylinder axized on the axis of the disk, a roll of paper covering this cylinder's surface, and a straight bar situated parallel to this cylinder's axis and resting with enough of pressure on the surface of the primary registering or

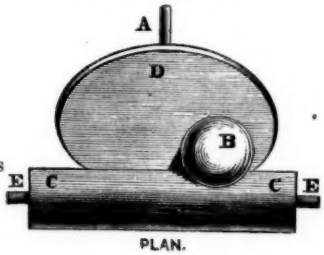


SIDE ELEVATION.



FRONT ELEVATION.

D, the Disk.
A, the Axle of the Disk.
C, the Cylinder.
E E, the Axle or the Journals of the Cylinders.
B, the Ball.



PLAN.

the indicating cylinder (the one, namely, which is actuated by its contact with the ball) to make it have sufficient fractional coherence with that surface, and by having this bar made to carry a pencil or other tracing point which will mark the desired curve on the secondary registering or *the recording* cylinder. As, from the nature of the apparatus, the axis of the disk and of the secondary registering or the recording cylinder ought to be steeply inclined to the horizontal, and as, therefore, this bar, carrying the pencil, would have the line of its length and

of its motion alike steeply inclined with that axis, it seems that, to carry out this idea, it may be advisable to have a thread attached to the bar and extending off in the line of the bar to a pulley, passing over the pulley, and having suspended at its other end a weight which will be just sufficient to counteract the tendency of the rod, in virtue of gravity, to glide down along the line of its own slope, so as to leave it perfectly free to be moved up or down by the frictional coherence between itself and the moving surface of the indicating cylinder worked directly by the ball.

A Process for Permanently Preserving Iron from Rust (or Oxydation).

Dr. Wm. H. Sterling is making known his system for preserving the entire structure of iron.

He says:

"The nature of my invention consists in the impregnation and saturation of the structure of the metal, iron, with a *non*-oxydizing or *non*-oxydisable substance or substances, by means of forcing these *non*-oxydizing or *non*-oxydisable substances into the intercellular or interstitial spaces of the metal by suitable pressure, while the iron is in a properly heated and expanded condition, induced by heating the iron in a vacuum, or in a simple chamber, as hereinafter described."

As the invention is capable of being variously mechanically applied, as the different forms of iron articles to be preserved, and the non-oxydisable substances used may require, it is not necessary to describe all of the various mechanical means which can be used in its application; he therefore gives only one of the methods by which his invention may be applied, and which he recommends as being eminently practical and useful:

"A vessel of iron, or any suitable material of sufficient strength, is made in the form and size best adapted to the shape and dimensions of the iron article to be treated, with the lid so constructed that the vessel may be closed hermetically, and at the bottom suitable pipes are arranged for conveying steam and water, alternately, for the purpose of heating and cooling the interior, as hereinafter described."

Suitably connected with this vessel is a power pump or forcing apparatus for producing the necessary pressure, also the proper appliances for obtaining a vacuum.

The iron to be treated is now heated to the desired temperature, as hereinafter stated, and placed into the above vessel, the top closed hermetically, and dry or superheated steam turned into the above-described pipes at the bottom, to keep the metal at the required temperature; also, at the same time, an atmospheric vacuum is produced by an ordinary air-pump connected with the chamber; the proper quantity, sufficient to fill the vessel, of pure paraffine or paraffine in solution with one of the pure heavy mineral oils, having been also previously heated to the required temperature, is now let into this chamber and forced, under the proper pressure from the forcing pump, into the intercellular or interstitial spaces of the iron, those spaces having so greatly enlarged by the expansion of the metal from the heat and removal of the atmospheric pressure as to most readily admit the subtle, penetrating *non*-oxydizable hydro-carbon preservative in sufficient quantity to for ever after protect the entire structure of the iron from oxydation or rust by any of the ordinary corrosive or oxydizing elements. When the iron has remained under this liquid pressure a sufficient time, it is gradually cooled by turning cold water instead of steam into the pipes, the pressure being kept up, however, until the iron is cool.

Certain qualities of iron may be treated without the atmospheric vacuum, but as the iron expands very much more aud greater pressure is obtainable by its employment, and the additional cost not to be considered, he recommends its use as most desirable.

We do not know to what extent the value of the process has been proved by time.

ON THE AMALGAMATION OF IRON AND OF SOME OTHER METALS.*

By P. CASAMAJOR.

From "Journal of the Society of Arts."

At the last meeting of this Society I was to speak to you on amalgamation of iron, but was prevented by the lateness of the hour from reading the paper I had ready for you. Since that evening I have learned a great many things about iron amalgam, one of which is, that most of the processes that I was to describe had already been published, although in a very succinct form, about nineteen years ago. This discovery would have prevented me from appearing before you to-night if I had not found that the subject is deemed by chemists, to whom I have shown samples of amalgamated iron, to be not only new, but very interesting. I have, besides, much new matter to communicate, among which is a new process for amalgamating iron, which is so simple and economical that all the other processes are rendered obsolete and useless.

That iron will combine with mercury is known to all chemists, although it is not deemed an easy operation, and we may find in the books several processes for accomplishing the combination. One of these, which I believe is due to Sir Humphry Davy, consists in immersing sodium amalgam in a saturated solution of ferrous chloride or sulphate. In another process, zinc amalgam is brought in contact with iron filings, in presence of a solution of ferric chloride. The filings become coated with mercury. In still another process, the electrolysis of ferrous sulphate gives iron amalgam when the negative electrode is formed of mercury. By subjecting the resulting amalgam to enormous pressures a residuum of pretty firm consistency is obtained, which is composed of about equal parts of iron and mercury.

The processes of amalgamation which I am to describe to you this evening, give products which have nothing in common with these iron amalgams. The samples of iron amalgam, such as I have here, are obtained from commercial wrought-iron, from cast-iron, and from steel, without altering the original shape of the material, and are analagous to the amalgam made from commercial zinc which we use in voltaic batteries.

Before giving you the results of my labors, I must give you a succinct account of the researches of Cailletet, which came to my knowledge as follows:—Before presenting myself before you at the regular meeting, it had been my endeavor to ascertain whether the results I was to announce were really new. Neither by my own exertions nor by inquiry from other chemists had I been able to discover that I had been forestalled, and had I confined my attention to iron, I would not have been aware —perhaps even now—of the existence of a prior claimant.

Having turned my attention to aluminium, I had occasion to consult Watts's "Dictionary of Chemistry," on the subject of aluminium amalgam, and came upon the following:—"According to Cailletet (*Comptes Rendus*, vol. xliv., p. 1250) aluminium (also iron and platinum) may be superficially amalgamated by contact with ammonium or sodium amalgam and water; also when it is immersed in acidulated water in contact with metallic mercury, forming the negative electrode of a voltaic battery."

On consulting the 44th volume of the *Comptes Rendus*, I found, at p. 1250, a memoir presented to the Academy of Sciences by Messrs. Chevreul and Dumas, at the sitting of June 15th, 1857, the title of which is "On the Influence of Nascent Hydrogen on Amalgamation," by M. L. Cailletet. The author uses ammonium amalgam, with which he agitates pieces of iron, aluminium, or platinum, and he finds that these metals become coated with mercury. The amalgam of sodium produces the same effect, only water is necessary to the reaction. If the surface of the sodium amalgam is covered with naptha no action takes

* Read before the American Chemical Society.

place, but one drop of water is sufficient to produce the desired effect.

If in a vessel containing mercury and acidulated water, we place the electrodes of a battery, and if the negative electrode be a piece of sheet iron in contact with mercury, the iron will be amalgamated as soon as hydrogen appears on this electrode.

From these experiments Cailletet concludes that amalgamation in these cases is due to nascent hydrogen, and he seems throughout his memoir to be so intent upon proving this point, that every other circumstance is mentioned in the most cursory manner. We may be allowed to doubt whether by covering sodium amalgam with naphtha, so that when iron comes in contact with the amalgam it is already covered with a film of naphtha, we have placed the iron in the best condition to combine it with mercury, and whether the non-combination under these circumstances is very conclusive of the necessity of nascent hydrogen to determine the combination between iron and mercury.

The following experiment with a mercuric salt carries more weight with it:—The author wishes to show that amalgamation, in the case of iron and platinum, is due to nascent hydrogen, and not to the electrical condition of the iron or platinum electrode. He takes the case of the electrolysis of salts of copper, silver, and mercury, and recalls that at the negative electrode we obtain metallic copper, silver, and mercury, but no hydrogen. If we have a salt of mercury subjected to a voltaic current, the negative electrode being made of iron or platinum, we may notice, after a while, that globules of mercury appear on this electrode, but they show no tendency to combine with it. If, now, the electrodes are withdrawn from the mercury salt, and placed in a vessel holding acidulated water, as soon as the voltaic current passes and hydrogen escapes at the negative electrode, the globules of mercury spread on this electrode, and it becomes amalgamated.

The above account of the memoir presented by Cailletet, contains substantially everything there is in it. The circumstances mentioned in "Watts's Dictionary" that the amalgamation obtained on iron and platinum is merely superficial, does not appear, even by implication, in the original paper.

Amalgam of sodium and ammonium, and the voltaic battery, these are the agents mentioned by Cailletet; these were also the agents that I used a month ago to determine the combination of iron with mercury. Although I now use a much simpler and a cheaper process, which I propose to describe in a few minutes, there are some points in connection with alkaline amalgams and with the action of the voltaic current which may be studied with advantage.

Amalgam of potassium, which I first used for amalgamating iron, behaves in every way like amalgam of sodium. Sodium, however, behaves somewhat differently from potassium towards mercury, the combination with sodium taking place with greater violence, being accompanied by a flash of sodium light, and the escape of alkaline vapors which are far from agreeable. These unpleasant manifestations may be reduced to a minimum by combining sodium at first with a very small quantity of mercury—a quantity not more than a fifth of the weight of the sodium. This gives rise to a violent reaction, but subsequent additions of mercury produce less and less effect, while, by bringing small pieces of sodium successively into a comparatively large mass of mercury, every fresh piece of sodium produces the same effect as its predecessor.

If the sodium amalgam has sodium enough in it to make it pasty, it will cover iron with a silvery coat. This coat may be rubbed off, leaving the oxidised surface unaltered. If brought in contact with water, or, still better, with a solution of sal-ammoniac, the sodium amalgam is decomposed and the mercury will sink into the iron. If the sodium amalgam is liquid it will adhere in little drops all over the surface of a piece of iron shaken up in it; by the action of water, of acids, or of sal-ammoniac, the droplets will spread on the iron, which will become amalgamated.

Ammonium amalgam will give up its mercury to iron when rubbed with it very persistently. Even then there are in every piece of iron certain spots where the mercury will not adhere. The intervention of acidulated water, by decomposing ammonium amalgam with great

energy, facilitates the amalgamation of iron in these difficult portions.

From the foregoing remarks you will understand that the maximum of good effect may be obtained from a certain amount of sodium, by the following method of procedure, while the combination of iron with mercury is very thorough and rapid:—We take four porcelain dishes and place them in a row, so that the piece of iron to be amalgamated may be placed successively in each. The first dish contains a liquid sodium amalgam; the second a solution of sal-ammoniac; the third water, acidulated with either sulphuric or hydrochloric acid; and the fourth aqueduct water. The piece of iron to be amalgamated is taken up with tongs, and agitated in contact with the sodium amalgam of the first dish. The operation covers it with liquid mercury containing sodium amalgam. When the surface seems sufficiently coated, the iron is left for a few seconds in the solution of sal-ammoniac, on emerging from which, it is found covered with the curious and interesting compound which we call ammonium amalgam. The piece of iron is placed next in the acidulated water, and finally in aqueduct water, to wash off the acid.

This series of operations is generally sufficient to leave a good coat of mercury on a piece of iron. If there should be spots left bare, a second series of immersions is generally sufficient to leave the surface perfectly covered. I need not say that the surface of the iron must be previously made clean by immersion in diluted acid.

By making the negative electrode of a voltaic battery of iron, and placing it in contact with mercury and with acidulated water, the iron will, after a time, become amalgamated. I have obtained the same result by a single voltaic element, the positive plate of which is a piece of zinc, and the negative plate a piece of iron, one portion of which is in contact with mercury at the bottom of the cup, the exciting fluid being acidulated water. An addition of chloride of sodium to the liquid in the cup seems to hasten the reaction.

Iron may be amalgamated also, by the use of zinc amalgam. This process gives the best results, and renders superfluous all the other processes we have mentioned. The use of zinc amalgam for the purpose had been attempted before, as for instance, in the process I have mentioned, where iron filings are rubbed with zinc amalgam in presence of a solution of ferric chloride, the reaction being assisted by heat. I also find in "Watts's Dictionary" that, "according to Aikin, iron amalgam is formed by the action of zinc amalgam on ferrous chloride." No particulars are given about this process, but the results must have been, to say the least, difficult to obtain, as we find, immediatey after that, "according to Damour, it cannot be obtained in this way."

I came upon the process I am about to describe, by a mere chance. I was trying to test the soundness of the theory of Cailletet, which attributes the amalgamation of iron to the presence of nascent hydrogen. In a beaker glass I had placed mercury, and over it acidulated water, and also a horse shoe nail of Norway iron, which rested on the mercury. A moderate escape of hydrogen took place from the surface of the iron nail; but after twenty-four hours no trace of amalgamation had appeared, which showed very conclusively that unassisted nascent hydrogen was certainly not sufficient to do the work. Having to amalgamate a small piece of zinc for another experiment, I found that I had no other mercury within my reach than the one on which the nail of Norway iron rested. As I had given up hopes of accomplishing anything by this arrangement, I had no scruples to use the mercury in this beaker glass, and in it I placed my piece of zinc; the result was that the escape of hydrogen from the nail increased very perceptibly, which circumstance induced me to leave the zinc in the mercury. On looking again at the iron nail I found it amalgamated and partly sunk into the mercury.

To amalgate iron with zinc amalgam, mercury should be placed in a vessel and covered with dilute sulphuric or hydrochloric acid. If, now, a piece of iron is agitated in contact with the mercury and the acid, no combination will take place; but if pieces of zinc are placed in the mercury, in a few minutes iron placed in the above conditions will become coated with mercury. If, after a while, the power of the mercury seems to decline,

more zinc must be added. The zinc is only attacked when iron, or some other metal more electro-negative than zinc, is brought in contact with the zinc amalgam and the acid, so that the expense in zinc is very slight.

The coat of mercury left on iron by the various agencies I have mentioned is not a superficial layer, for the mercury sinks into the metal, modifying its physical and chemical properties. In the case of pure soft iron it is difficult to notice any decrease of tenacity after amalgamation. With hard-tempered steel, however, the increased brittleness is very marked. In the case both of iron and steel, a fresh fracture shows that mercury had penetrated deeply into the metal.

Of the chemical change operated on iron by amalgamation, I can call attention to only one point, which is, the analogy which exists with the properties of zinc amalgam. When a piece of zinc* has been amalgamated it is not attacked by acids as readily as zinc free from mercury; but if a piece of amalgamated zinc is connected to a piece not amalgamated, the amalgamated zinc becomes the positive plate in a voltaic couple. These properties of amalgamated zinc are found, although in a less degree, in amalgamated iron. Two pieces of sheet iron, presenting exactly the same surface, were placed in diluted sulphuric acid, so that the action of the acid was exactly the same on each. One of these plates was amalgamated, the other not. After prolonging the action for over two hours, it was found that the amalgamated plate had lost two-thirds as much in weight as the other.

If, however, two pieces of iron†—one amalgamated and the other not—are connected by a metallic wire, the amalgamated plate is attacked, and the other plate plays the part of a negative.

In iron amalgam, made in the way I have described, the quantity of mercury in combination is very small. A piece of sheet iron, presenting on both sides a total surface of three square inches, was amalgamated and left to soak in mercury for over an hour. The mercury was then wiped off very thoroughly, and the piece of sheet-iron weighed. The increase over the original was thirteen centigrammes, which showed an absorption of mercury equal to a little over four centigrammes per square inch. The increase of weight in this thin sheet of iron was only three and a half per cent. Still, in this sheet, the fracture was silvery, and globules of mercury stood on the rough edge of the fracture.

For the sake of comparison I treated a piece of sheet zinc, of the same dimensions, in the same manner, leaving it, however, only a few minutes in contact with mercury. After rubbing off the excess of mercury, and weighing, I was surprised to find a loss instead of a gain in weight. This was doubtless due to a certain quantity of zinc being dissolved by the mercury.

I must now, to fulfill the programme offered by the title of this paper, speak to you of the amalgamation of some other metals, by which are meant some of those whose point of fusion is very high, and which have always shown themselves exceedingly adverse to combining with mercury. Those that I have tried are platinum, palladium, aluminium, nickel, and cobalt. Except in the case of aluminium there seems nothing of peculiar interest to notice about their amalgams, after what has been said of iron amalgam. These metals all take mercury very readily by the processes which are effective in the case of iron. Aluminium deserves mention on account of its eccentric behavior; it seems to take mercury in the same manner as the other metals, but shortly after being taken out and dried, it becomes very hot, the mercury seems to boil, and the aluminium remains covered with a chalky crust. On brushing this off, the metal is found beneath without a sign of amalgamation.

In conclusion, I will point out that two inquiries suggest themselves in connection with these amalgams. One relates to the determining cause of these combinations, and the other is whether these amalgams — particularly amalgam of iron—can be applied to useful purposes. To both these questions the answer is, that I have nothing satisfactory to offer, although a great many things suggest

* This observation relates to impure zinc. Amalgamation makes impure zinc behave towards acids like pure zinc.

† This is more easily noticed with steel than with pure soft iron.

themselves as plausible. I am sure you will readily excuse me from presenting theories that are merely plausible, as to the cause of these phenomena, and feel equally certain that I need offer no apology to this enlightened auditory for calling their attention to these combinations of mercury with iron and other metals, because they have not yet become of practical utility, although it may be befitting to offer an apology for the manner in which the task has been performed.

PRIME MOVERS.*

From "Nature."

II.

We now come to Newcomen, who I think may fairly be looked upon as the father of the steam-engine in its present form. No. 1,942 is a model of his engine, which is further illustrated by a rare engraving (of 1712), the property of Mr. Bennet Woodcroft.

Here we have the steam boiler, the cylinder, the piston and rod, the beam working the pumps in the pit, the injection into the cylinder and the self-acting gear, making altogether a powerful and an automatic prime mover.

That conscientious writer, Belidor, to whom I have frequently referred, says, that he hears of one of these machines having been set up in the water-works on the banks of the Thames at York Buildings. I may say to those who are not aware of it, that those works were situated where the Charing Cross Station now stands. On a Newcomen engine being erected in France at a colliery at Fresnes, near Condé, Belidor paid several visits to it in order that he might understand its construction thoroughly, and be thereby enabled to explain it to his readers. He has done so with a minuteness and faithfulness of detail, in description and in drawings, that would enable one to repeat the engine. This engine had a 30-inch cylinder with a 6-feet stroke of the piston and of the pumps. The boiler was 9 feet in diameter and 3½ feet deep in the body; it had a dome which was covered with masonry 2 feet 6 inches thick to hold it down against the pressure of the steam. It had a safety-valve (the Papin valve) which Belidor calls a "Ventouse," and says that its object was to give air to the boiler when the vapor was too strong. It had double vertical gauge cocks the function of which Belidor explains; it made fifteen strokes in a minute; and he says that being once started it required no attention beyond keeping up the fire, that it worked continuously for forty-eight hours, and in the forty-eight hours unwatered the mine for the week, whereas previously to the erection of the engine the mine was drained by a horse-power machine, working day and night throughout the whole week and demanding the labor of fifty horses and the attendance of twenty men to keep the water down. I should have said that the pumps worked by the steam-engine were 7 inches bore and were placed 24 feet apart vertically in the pit which was 276 feet deep, and that each pump delivered into a leaden cistern from which the pump above it drew.

After having given a most accurate description of the engine, Belidor breaks out into a rhapsody and says (I will give you a free translation) "It must be acknowledged that here we have the most marvelous of all machines, and that there is none other of which the mechanism has so close a relation to that of animals. Heat is the principal of its movements; in its various tubes a circulation like that of the blood in the veins is set up; there are valves which open and shut; it feeds itself, and it performs all other functions which are necessary to enable it to exist."

Smeaton employed himself in perfecting and in properly proportioning the Newcomen engine, but it was not until James Watt that the next great step was

* Address delivered by F. J. Bramwell, C. E., F. R. S., at South Kensington.

made; that step was, as we all know, the doing away with condensation in the cylinder, the effecting it in a separate vessel and the exclusion of the atmosphere from the cylinder. These alterations made a most important improvement in the efficiency of the engine in relation to the fuel consumed; but they were so simple that I doubt not, if examiners into the merits of patents had existed in those days, Mr. Watt would have had his application for a patent rejected as being "frivolous." We have here from case No. 1,928, a model made by Watt which appears to be that of the separate condenser and air-pump; we have also 8B which is a wooden model made by Watt of a single acting, inverted engine, having the top side of the cylinder always open to the condenser, and a pair of valves by which the bottom side of the piston can be put into alternate connection with the boiler and with the condenser, the contents of which are withdrawn by the air-pump. 3B from the same case is a model of a direct acting, inverted, pumping engine, made in accordance with the diagram 8B. 1B is a model of Watt's single acting, beam, pumping engine, while 2B is a model of Watt's double acting, beam, rotary engine. 10B from the same case is Watt's model of a surface condenser. To Watt we owe condensation in a separate vessel, exclusion of the air from the cylinder, making the engine double acting, employment of the steam jacket, and employment of the steam expansively, the parallel motion, the governor, and in fact all which made Newcomen's single acting, reciprocating, pumping engine into that machine of universal utility that the steam-engine now is, and not only so, but Watt invented the steam-engine indicator which enables us to ascertain that which is taking place within the cylinder and to see whether or not the steam is being economically employed. I have on the table before me a very excellent model of German manufacture, No. 2,137, illustrating an inverted, direct acting, pumping engine in its complete form, and I have also a model of French manufacture, the cylinder and other working parts of which are in glass; this shows a form of Watt's rotary, beam, condensing engine at one time in common use.

I do not say, however, that Watt was the first to make the suggestion of attaining rotary motion from the power of steam. Leaving out of consideration Hero's toy, Papin, as I have remarked, hoped to get rotary movement second-hand by working a water wheel with the water that had been raised by his steam-engine; moreover, as early as 1737, Jonathan Hulls proposed to obtain rotary motion from a Newcomen engine and to employ that motion in turning a paddle-wheel, to propel a tug-boat which should tow ships out of harbor, or even against an adverse wind. I have before me one of the prints of his pamphlet and in order that you may better appreciate his invention I have put an enlarged diagram upon the wall, and I think I may take this as the starting-point for saying a few words about the steam-engine as a prime mover in steam vessels.

We have in the collection, No. 2,150, Symington's engine tried upon the Lake at Dalswinton in 1788. Here a pair of single acting vertical cylinders give, by the up and down motion of their pistons, reciprocating movement to an overhead wheel; this wheel gives a similar motion to an endless chain which chain is led away so as to pass round two pairs of ratchet wheels loose upon two paddle shafts. By the use of a pair of ratchets the reciprocations of the chain are converted into rotary motion in one direction only, and that the driving direction of the two paddle wheels placed one behind the other. Symington's arrangement for obtaining the rotary motion always in one direction of his two paddle-wheels is very similar to that proposed by Jonathan Hulls for his single stern-wheel. Want of time forbids me to do more than just to allude to the names of Hornblower and Wolff in connection with double cylinder engines, engines wherein the expansion of steam is commenced in one cylinder and continued in another and a larger one.

I wish to say a few words which will bring before you the changes that have been made within a very few years in the construction of the marine engines. I may observe that when I was an apprentice the ordinary working pressure of steam, except in the double cylinder engine, was only 3 lbs. above atmosphere, and that there was in a marine boiler more pres-

sure on its bottom when the steam was down, due to the mere head of water in the boiler, than there was pressure in the top when the steam was up, due to the force of the steam; whereas now condensing marine engines work commonly at 70 lbs., and there is a boat under trial where the steam is, I believe, as high as 400 lbs.

To those who are curious on the subject, I would recommend a perusal of two Blue Books, one being the evidence taken before a Parliamentary Commission in 1817, and the other before a Parliamentary Committee in 1839; they will find there the weight of evidence to be that the only use of high pressure steam is to dispense with condensing water, and that as a steamboat must always have plenty of condensing water in its neighborhood, no engineer knowing his business, would suggest high pressure for a marine engine.

I have before me a model of a pair of engines which, although they were made not so very long ago (for I saw them put into the ship), have nevertheless an historical interest. This model shows Maudslay's engines of the *Great Western*, the first steamer built for the purpose of crossing the Atlantic. I think I am right in saying that 7 lbs., steam was the pressure employed in that vessel, and in order to extract the brine from the boiler it was necessary to use pumps as the pressure of the steam was not sufficient to expel the brine and to deliver it against the pressure of the sea.

Time does not permit of my touching upon the various improvements in boilers, condensers, expansive arrangements, and other matters which have gradually been introduced into our best engines for land and for ocean purposes. I have hung upon the wall a rough diagram showing a pair of oscillating engines as applied to driving a paddle steamer, and another showing a pair of inverted, compound cylinder engines to drive a screw propeller; a model of such a pair of engines with surface condensers and all modern appliances (being Messrs. Rennie's engines for the P. and O. Company's S. S. *Pera*, by which I have had the pleasure of traveling) is now before me.

I will conclude this part of the subject by saying that to the combination of science and sound practice is due the fact of the consumption of coal having been reduced from 5 lbs. per gross indicated horse-power per hour to an average of 2¼ lbs. and, in exceptional instances, to as small a quantity as 1½ lbs. per horse per hour.

Let us now devote a little of the time that is left to the consideration of the locomotive on the common road as well as on the railway. I have before me No. 2,145, a model of the actual engine of Cugnot, in the Conservatoire des Arts et Métiers, which, in 1769, journeyed—slowly, it is true, but did journey and did carry passengers—along the roads in Paris.

It is a most ingenious machine; it has three wheels, and the motive power is applied to the front, the castor, or steering wheel, so that engine and boiler turn with the wheel precisely as, within the last few years, Mr. Perkins has caused the engine and boiler to turn with the steering-wheel of his three-wheeled, common road locomotive. The steam causes the pistons in a pair of inverted, single acting cylinders to reciprocate, and their rods, by means of ratchet wheels, give rotary motion to the castor wheel, and thus propel the carriage. I think there is no doubt but that we must look upon this engine of Cugnot as the father of steam locomotion, as we must regard Symington's engine as the parent of marine propulsion. I have before me No. 1,926, Trevethick's engine of 1802; I have also before me a Blenkinsop rail, one that has been in actual use for many years, provided, as you will see, with teeth, into which a cogged flange on the side of the driving-wheel is geared to insure that tractive force should be obtained. This plan has been revived, within the last few years, to enable the steam locomotive to climb the Righi. A sketch of the Righi engine and rail is on the wall. It will be seen that the teeth instead of projecting from the side of the rail, are ranged between two parallel bars like the rungs of a ladder.

On the ground floor of the exhibition we have the veritable "Puffing Billy," an engine which began work in 1813, and got along without the aid of cogs, by mere adhesion upon plain rails; it is a rude-looking machine, but it labored up

till the date of the last Exhibition, doing its work for forty-nine years on the railway belonging to the Wylams Colliery, and, as tradition says, interesting George Stephenson, who, as a boy, saw it in daily operation.

On the ground-floor, also, we have 1,954, the "Rocket," with which, seventeen years after the starting of "Puffing Billy," George Stephenson carried off the prize in the Manchester and Liverpool Railway competion. The leading particulars of this engine are as follows: A pair of 7½ inch cylinders 1′ 5″ stroke, placed at a slight inclination driving 4′ 6″ wheels, the boiler, multi-tubular, having twenty-four three and a half inch tubes, while the fire is urged by the waste blast. Before alluding to this I ought to have mentioned that in one of the Blue Books to which I have called your attention—that which gives the evidence before the Commission in the year 1817—there is a statement by a witness that in those parts there are machines called locomotives, &c.

Once more I am compelled to say that time will not admit of my entering into any detail in respect of the modern locomotive, except to remark that by the aid of excellent boilers, of high-pressure steam (140 lbs. to the inch) of considerable, although rather imperfect expansion effected by the link motion, there is provided for the use of our railways a machine which in the "passenger" form is competent to travel with ease and safety 60 miles an hour, and in the "goods" form is competent to draw a load of 800 to 1,000 tons, and to attain these results with a very commendable economy in fuel. I have put on the wall two diagrams of locomotives of the convenient form for local traffic that we call tank engines, and I have before me No. 1,957*a*, a most beautifully made sectional working model of a Russian six-wheeled "goods" engine.

Within the last twenty years another description of steam-engine has acquired a prominent and important place among our prime movers; I allude to the portable engine, or to the portable engine in its more complete form of a self-propelling or traction engine. The general construction of these machines borders closely upon that of the locomotive. Very great attention has been paid to all their details, and the Royal Agricultural Society of England, by their excellent arrangements for periodical trials, have stimulated engineers to devote their best energies to the subject. No. 1,942 is a model of one of Aveling and Porter's common road, traction engines, capable also of acting as a source of power for driving farm-yard machinery or for effecting steam-ploughing. Upon the wall I have placed rough diagrams of another kind of traction engine—a kind wherein india-rubber tires are used; this is manufactured by Messrs. Ransome, Sims and Head, and I have also placed there diagrams of the ordinary portable engine and of another most useful kind of portable engine, viz., the steam fire-engine. I have there likewise a sketch of Hancock's common road steam coach, which for so many months regularly plied for hire from the Bank to Paddington in opposition to the ordinary horse omnibus. Hancock's carriage was a vehicle which, in my judgment, has never since been surpassed, and I am sorry to say never to my knowledge equaled as regards the various points which should be attended to in making a steam carriage to circulate safely among horse-traffic.

There is another way in which steam may be employed as a prime mover. We saw that water in the form of the "Trombe d'eau" could be caused to induce a current in air and thereby to blow a forge fire, and that a rapid stream induces a current in other water, and thus drains marshy lands. Similarly steam can be caused to induce a current in water and thereby impel the water so as to raise it to a height or to force it as feed-water into a boiler against a heavy pressure. When used for a mere pumping apparatus, such a mode of employing steam is very wasteful, because the steam is condensed by the water in large quantities and the water is needlessly heated at the expense of the steam; but when used in feeding a boiler into which, thus, the whole of the heat is taken, this objection does not apply. By means of that most elegant and scientific apparatus, the Giffard injector, it is possible, by a jet of steam, to economically induce a current in surrounding water, powerful enough to take the condensed steam itself and the water into the boiler

from which the steam had previously issued. No. 1,976, which I have before me, is a sectional model of a Giffard injector.

I believe it was I who first gave a popular explanation of the principle of action of the Giffard injector, and although a scientific congress is probably not the place for a popular explanation, I will venture to repeat it. The principle may be summed up in one word, "concentration." The steam that issues from an orifice of an area of 1, when condensed, has a sectional area (according to the original pressure of the steam) of only $\frac{1}{200}$th or $\frac{1}{400}$th or $\frac{1}{800}$th as the case may be, thus the velocity remaining the same and the weight the same, the energy of the steam issuing from an area of 1, is concentrated 200, 400, or 800 times upon the area due to the smaller transverse section of the liquid stream.

This concentration of energy is far more than sufficient to enable the fluid stream to re-enter the boiler from which the vaporous stream started, and so much more than sufficient, that it may be diluted by taking with it a certain quantity of water, which was employed in the condensation of the steam, and is required for the feeding of the boiler.

With a view to obtaining economy in fuel, many attempts have been made to employ some other agent than steam, as the means of developing the power latent in fuel, but it is imperative that I should dismiss these with a mere enumeration. A very interesting engine of this kind (because, excluding Hero's toy and smoke jacks, it is, so far as I know, the first proposition for obtaining rotatory motion by the aid of heat), was the fire wheel of M. Amonton, of which an account is to be found in the first volume of the "French Academy of Sciences," for the year 1699. On referring to that volume I do not see that it is stated in terms, that the machine was ever put to work, although it is said that M. Amonton made many experiments to convince the Academy of the practicability of his invention. M. Amonton proposes to have a metallic wheel revolving on a horizontal axis; the outer rim of the wheel was to be divided into a number of separate air cells, each of which had a channel so as to communicate with other cells, water-cells, arranged round the wheel nearer to the center than the air-cells; the air-cells as they passed over a fire were to be heated, and the air was to drive this water up to one side of the wheel, so as to keep that side always loaded, and thus give the wheel a tendency to revolve. The cells after leaving the neighborhood of the fire were to be cooled by passing through water to re-contract the air ready for the next operation.

No. 1,940, which is before me, is a model of Stirling's hot-air engine, but time does not remain to describe it.

Besides hot-air engines, we have had engines working by the explosion of gun-powder, and others working by the explosion of gases. No. 1,945 is Langen and Crossley's gas engine, from which I believe extremely excellent results have been obtained.

I will now ask you to look at a tabular statement which shows the consumption of fuel in some agricultural engines, when under trial, expressed in pounds per horse-power per hour, and also in millions of pounds raised one foot high by the consumption of 1 cwt. of coals. I told you how excellent were the results at which our agricultural engineers had arrived; you will see that one of those machines, working with 80 lbs. steam, and of course without condensation, has developed, not a gross indicated horse-power, but an actual dynamometrical horse-power, for $\frac{2}{3}$ 79 lbs. of coal per horse per hour, giving a duty of as much as 79½ millions. This high result was obtained by the excellence of the boiler and of the combustion, as well as by that of the engine. If you look at the column of evaporation you will find that as much as 11.83 lbs. of water were converted from the temperature of the boiling point into steam by the combustion of 1 lb. of coal; this was due, not to the merits of the boiler alone, but to the extraordinary ability of the stoker, and to the care and labor bestowed, a care and labor far too expensive to be employed in practice. But should not we engineers endeavor to ascertain whether we cannot by mechanical means, practically, with certainty and cheapness, procure an accuracy of combustion as great, or even greater than that which can be got by the almost superhuman attention of a highly-trained man, who at the end of

four hours of such work is utterly exhausted? Many forms of fire-feeders have been attempted and used with more or less success, but I cannot help thinking that in order to obtain the accurate proportioning of air and fuel, by which alone we can get efficient and economical combustion, we shall have to turn our attention in the direction of dealing with the fuel in a comminuted state, either by converting it into gas, as is done by our president, Dr. Siemens, by availing ourselves of liquid fuel, or by employing the process of Mr. Crampton, and making the fuel into an impalpable powder, that may be driven into the furnace by the air which is there to consume it.

By these, and by other means, we may hope to improve combustion. By strict attention to the proportioning of the parts of the boiler we may hope to make the best use of this improved combustion. By higher initial pressure, by greater expansion, and by the general employment of condensation, wherever practicable (and by the use of the evaporative condenser there are very few cases in which it is not practicable), we may trust that the steam-engine, even on its present principle, will be rendered more economical than it has ever yet been, and may give us more than that one-eighth or one-ninth of the total force residing in the fuel which now alone we get under the very best and most exceptional conditions. A large loss, however, must with steam-engines, as we now know them, always be incurred. We cannot hope to deal with initial pressures and temperatures corresponding with steam of a density equal to that of water, nor to carry expansion down to the point where ice would be formed in the condenser. But wonderful as the steam-engine is, worthy as it was and is of Belidor's eulogium (which I read to you), we know it is not the only heat motor, and we are aware that there are other forms of such motors which, theoretically at all events, promise higher results.

By improvements in the existing steam-engine, by the invention and development of other heat motors, by the employment of the power of water and of wind, either as principal motors or as auxiliaries, we may look to further progress in the machines—the subject of my address—"Prime Movers."

I have brought before you, of necessity hastily, and therefore (and also on account of my own incapacity for the task) imperfectly, the leading improvements which have been made in prime movers from the date of the water-wheels of Vitruvius to the best-devised steam-engines of our own day. These improvements have been effected by men like Papin, Savery, Newcomen, Watt, Symington, Stephenson, and others, who were not mere makers of engines, but were men full of an ardent love of their noble profession, who followed it because of the irrestible attraction it possessed for them; followed it from their boyhood to their grave, and in that very following found their great reward. These men undoubtedly possessed that combination of science and practice, which combination, Dr. Tyndall has told us, is necessary if either science or practice is to continue to live; for, to use his expressive language, without this combination they both die—die of atrophy; the one becomes a ghost, the other a corpse.

We have every reason to believe that this combination will rapidly become even more fully developed, not only in the engineers of the present day, but in those of the next and of succeeding generations, and to such men as these we may trustfully leave the continued improvements of prime movers, resting content with the knowledge that a more general application of these machines must of necessity follow such improvements, and that the day will soon dawn when, in no civilized country, will there continue to be the temptation to employ intelligent humanity in the brutal labor of the turnspit, or of the criminal on the treadwheel.

A CORRESPONDENT of the *Western Mail* mentions a rumor that overtures have been made by the Great Western Railway Company for the purchase of the Taff Vale Railway. It is stated that the Great Western would guarantee seven and a half per cent. to all original shareholders in perpetuity, and secure four and a half to five to all subsequent holders.

A CENTURY OF MINING AND METALLURGY IN THE UNITED STATES.

Centennial Address of Hon. ABRAM S. HEWITT, President-elect of the American Institute of Mining Engineers.

GENTLEMEN: If my first words were other than those of thanks for the high honor of being called to preside over the American Institute of Mining Engineers, I should do injustice alike to you and to my own sense of the obligation under which I have been placed by your voluntary choice. When the position was first suggested to me, I resolutely declined to allow the use of my name, on the ground that, by training and occupation, I was not entitled to this honor, which, it then seemed to me, should be conferred only on a professional engineer. In fact, the history of the Institute, which had honored itself, as well as my distinguished predecessors, David Thomas, Rossiter W. Raymond, and Alexander L. Holley, by elevating them to its highest office, seemed to indicate the line and the limit of safe precedent, in which I did not then see how I could be included.

But my scruples were finally removed by the consideration that, as in the course of human industry, the pioneer, of whom Mr. Thomas was so marked a type, must precede the mining engineer, so fitly personified in Dr. Raymond, and be followed by the mechanical engineer, whose incarnation we behold in Mr. Holley; so all these must be supplemented by the man of affairs and finance, in order that "enterprises of great pith and moment" may be prosecuted to a successful issue. I felt, therefore, that I had no longer any right to resist your preference, or to deprive myself of what I must regard as the crowning honor of an active career.

On an occasion like the present it seems appropriate to review the history in this country, during the last hundred years, of those industries which the Institute of Mining Engineers specially represents. There is much in the story with which other members of this body are more familiarly acquainted than myself; yet I fancy that to all of them, and not less to our distinguished and most heartily welcome guests from abroad, a comprehensive outline of the progress of mining and metallurgy in the United States will prove interesting. I ask your attention, therefore, to a condensed account of that subject, embracing a statement of the beginnings of the industry on our shores, of the notable events attending its increase, and of its present condition after a hundred years of national life. The extent and rate of our progress will be shown more clearly by figures than by words; and I shall offer a couple of tables, carefully compiled from the best available sources, and showing the production of coal and iron throughout the world. This general survey would be incomplete without some account of the legislation of the Federal government with regard to mining, the principles upon which it has been based, the effects which it has produced; and, finally, I shall attempt to point out some causes and agencies which, under our institutions and habits, may be, in my opinion, relied upon to effect certain great ends of technical efficiency, political economy, and social equity, which our government has not attempted, and could not fairly be expected, to achieve.

Many of the topics I have named are more or less familiar to me in my experience as a man of business, a student of public affairs, and a zealous inquirer into the social and industrial problems of the present generation. But the collection and arrangement of facts in my possession, the search for other facts to complete the record, and the orderly expression of the whole in connected form, would have been a labor at this time utterly beyond my powers, already overtaxed by intense and continuous occupation in another sphere, had I not been able to avail myself of the assistance of Dr. Raymond, whose thorough acquaintance with a large portion of the field I was attempting to cover, and whose ready comprehension of the nature of my plan enabled him to render me a service so essential that I cannot consent to omit an explicit recognition of it.

Mining enterprises were among the motive powers to the exploration, conquest, and colonization of the New World. The desire to find a shorter route to the profitable trade of India, and the desire to conquer new territory, wherever it might be found, in the name of some Catholic or Protestant sovereign of Europe, were accompanied, both in North and South America, by eager hopes of the discovery of gold and silver.

The history of the plunder of the metallic wealth and the development of the mineral resources of Mexico and South America, does not lie within my present purpose. The early enterprises of this kind in the northern part of the continent were less successful, though the progress of two hundred years has made them more beneficial to national prosperity, for reasons which I shall, perhaps, be able to indicate.

Gold was found in moderate quantities in use among the Indian tribes of the present Southern States. The Spaniards under De Soto, following this clue, and led on by stories, exaggerated or misunderstood, of their Indian guides, made a wide superficial exploration in search of the origin of this treasure. They are supposed to have excavated many of the diggings in North and South Carolina and Georgia, which are now overgrown with forests. But no rich deposits appear to have been discovered, and no permanent operations undertaken.

In the great charter of King James, by which, in 1606, the right to explore and settle the North American Continent from the thirty-fourth to the forty-fifth parallel, was granted to the London and Plymouth Companies, it was provided that one fifth of the gold and silver, and one-fifteenth of the copper, which might be discovered, should belong to the crown. One of the earliest expeditions of Captain John Smith, in Virginia, was the exploration of the Chickahominy River, in the hope that it might constitute a water-way to the Pacific Ocean; and one of the next events in the history of the same colony was a mining excitement, such as would be called in our California tongue a "stampede," caused by the supposed discovery of gold; in which, fortunately, John Smith did not avail himself of his official position to take "stock." It is a curious circumstance that gold really occurs in that region, though the glittering dust, of which a ship-load was sent by the deluded colonists to the jewelers of London, proved to be but mica or iron-pyrites; and it seems probable (albeit this suggestion is not based upon any explicit record known to me) that the presence of gold among the Indians, and the discovery of specimens of the quartz or slates of Virginia, containing visible particles of it, gave rise to the general excitement, under the influence of which, without further tests of value, a large amount of worthless material was collected, to the neglect of necessary and profitable industry. From this point of view the Jamestown mining fever was the prototype of many that have since occurred—all of which may be summed up in the general expression, that the mine "did not pan out according to the samples."

A more promising industry was inaugurated at the same time by the sending of a quantity of iron ore from Jamestown to England in 1608. This ore, smelted in England, yielded seventeen tons of metal probably the first pig-iron ever made from North American ore. In 1620, a hundred and fifty skilled workmen were sent to the colony to erect iron-works; and it is said that a fund, subscribed for the education of the colonists and Indians, was invested in this enterprise, as a safe and sure means of increase. But, in 1622, an Indian massacre broke up the enterprise; and both the manufacture of iron and the education of citizens and Indians have been obliged, ever since, to rely upon other sources of support.

For an interesting collection of facts relative to the beginnings of the iron industry of the American colonies, I refer you to the forthcoming work on that subject, by our fellow-member, Mr. John B. Pearse, to whose courtesy I am indebted for the opportunity to consult the advance sheets of a portion of the book.

According to the statement of Colonel Spotswood, quoted by Mr. Pearse, it appears that, previous to 1724, neither New England, Pennsylvania, nor Virginia, possessed blast furnaces. Their product of iron was from bloomeries only. According to Prof. Hodge, quoted by Prof.

Whitney, however, a furnace was built at Pembroke, Mass., in 1702; and another authority states that, in 1721, New England possessed six furnaces and nineteen forges. In 1719 was passed the famous resolution of the British House of Commons, "that the erection of manufactories in the colonies tended to lessen their dependency on Great Britain." Only the earnest protest of the colonial agent prevented the prohibition at that time of the American iron manufacture. The next thirty years witnessed two instructive contests. The first was that of the colonial with the domestic pig-iron manufacture—a competition in which America was favored by the abundance of her vegetable fuel (the employment of mineral coal in iron-making not having yet found introduction), in comparison with the rapidly waning forests of Great Britain. The British manufacture being protected by heavy duties on colonial pig-iron, the latter began to be more and more worked up into bar-iron, nails, steel, etc., at home; and this brought on a new competition with the British manufacturers of these articles. In 1750, a further legislative attempt to regulate this trade was made by Parliament, which decreed the admission of colonial pig-iron duty free, but prohibited the erection in America of slitting, rolling, or plating mills, or steel furnaces, ordering that all new ones thereafter built should be suppressed as "nuisances."

It will be recollected that arbitrary acts of this kind, for the destruction of our infant manufactures, were among the grievances cited in the Declaration of Independence. The extent of the American iron manufacture, during the ante-revolutionary period, can be inferred only from scanty records of exports. These, beginning in 1717 with three tons, had increased, in 1750, to about 3000 tons; in 1765, the total is reported at 4342 tons; and in 1771, at 7525 tons, the maximum annual export. The outbreak of the war of course put an end to exportation and caused a great demand for war material, which occupied and rapidly extended the means of manufacture possessed by the country. The expanded iron industry suffered a severe collapse when, at the close of the war, not only this demand ceased, but the reopened ports admitted large quantities of foreign iron—the successful employment of mineral coal, the steam engine and puddling having by that time laid the foundation of English supremacy in the iron manufacture.

The earliest copper-mining company of which we find any record—according to Prof. Whitney, in his excellent work on the metallic wealth of the United States, the earliest incorporated mining company of any kind—was chartered in 1709, to work the Simsbury mines, at Granby, Conn. These mines were abandoned in the middle of the eighteenth century, afterwards bought by the State of Connecticut, and used as a prison for sixty years. Mining was resumed in them about 1830, and after a few years they were again abandoned. The ores were mostly shipped to England, and seem to have been lean. The deposit belongs to the class of irregular bunches, nodules, seams, or limited beds, in the New Red Sandstone, near its junction with trap. This formation was the scene in New Jersey, also, of early mining activity. The Schuyler mine, near Belleville, on the Passaic, was discovered about 1719, and proved more profitable to its owners before the Revolution than it ever has been since that time, to any of the series of individuals and companies that have expended large sums in its development. In fact, the chief blessing conferred upon mankind by the Schuyler mine arises from the circumstance that the first steam engine ever built wholly in America was constructed in 1793-4, at the small machine shop attached to the smelting works at Belleville, my father being the pattern-maker in the party of mechanics sent out by Boulton & Watt for the purpose of erecting an engine for the Philadelphia Water-works in Center Square. In 1751 a copper mine was opened near New Brunswick; and the Bridgewater mine, near Somerville, was operated previous to the Revolution, though even then, it is said, with much loss of capital. New Jersey's record in copper-mining is not a cheerful one; but her unsurpassed ranges of iron ores may well console her. Betrayed by the treachery of Triassic and trap, she can flee to the shelter of the crystalline schists. Pennsylvania was not without her copper-mining in the colonial period, the Gap mine, in

Lancaster County, having been opened in 1732.

Already during the colonial period the first red gleams of the future glory of the Lake Superior mines had appeared. The intrepid Jesuit fathers, Marquette and others, who penetrated the wilderness from Acadia to the Gulf, to carry both the Cross of their religion and the Lilies of their Sovereign, had made extensive explorations on the Upper Peninsula, and published glowing accounts of the abundance of copper, to which later travelers added legends of gold and precious stones. Before them, the Indian tribes, whose stone tools now furnish subjects of inquiry to the Archeologist, had wrought rudely upon the deposits which nature had left in a condition so exceptionally pure as not to need, for the production of limited amounts of metal, the intervention of metallurgical processes. The first recorded mining operations on the part of white men were those of Alexander Henry, near the Forks of the Ontonagon, in 1771. As is well known, however, the active development of this region dates from the publication of Houghton's *Geological Report*, in 1841, and the extinguishment of the Chippewa title by the treaty of 1843.

Lead mining in this country may also claim an ancient origin—as we reckon antiquity. As early as 1651, Governor John Winthrop received his famous license to work any mines of "lead, copper, or tin, or any minerals as antimony, vitriol, black-lead, alum, salt, salt-springs, or any other the like," and "to enjoy forever said mines, with the lands, woods, timber, and water within two or three miles of said mines." As he received also a special grant of mines or minerals in the neighborhood of Middletown, Conn., it is not unlikely that the old Middletown silver-lead mine, the date of the discovery of which is not precisely known, was opened by him or his successors. The nickel and cobalt mines near Chester, in Connecticut, once held to be very promising deposits, are also believed to have been originally worked by Governor Winthrop; but nickel was not valuable in those days; and the lead and copper in these ores do not seem to have been abundant. Unfortunately, now that nickel and cobalt are so valuable as to repay amply the cost of extracting them when they are present in a small percentage only, these Connecticut ores no longer correspond (if indeed they ever did) to the analysis and accounts formerly given as to their niccoliferous character.

The old Southampton silver-lead mine, in Massachusetts, well known to mineralogists, was commenced in 1765, by Connecticut adventurers; but its operations were suspended by the Revolutionary war. Lead mines in Columbia and Dutchess Counties, N. Y., were also worked at an early period; and, no doubt, all over the country occupied or controlled during the war by the American forces, there were small and desultory surface operations, furnishing lead for the use of the army.

The Indians inhabiting the Mississippi Valley before the advent of the whites probably did not understand the metallurgy of lead. Galena has been found in the Western mounds, but, it is said, no lead. In 1700 and 1701 Père Le Sueur made his famous voyage up the Mississippi, discovering, as he claimed, many lead mines. Led mining was begun in Missouri in 1720, while that country belonged to France, and under the patent granted to Law's famous Mississippi Company. Mine la Motte, named after a mineralogist who came over with Renault, the superintendent, was one of the first discoveries. It has been in operation at intervals ever since, and is now successfully managed by Mr. Cogswell, a member of our Institute, who may I think, truthfully claim that he has charge of the oldest mining enterprize still active in the United States. The ores yield a small percentage of nickel and cobalt, as well as lead.

It was in 1788 that Dubuque obtained from the Indians the grant under which he mined until the year of his death, where the city now stands which bears his name. The land was subsequently ceded to the United States by the Indians, and the representatives of Dubuque were forcibly ejected.

Such, then, was the condition of our mining industry at the commencement of our national existence. We occupied but a strip of territory on the Atlantic; and even in that limited area we had scarcely learned the nature and extent

of the mineral resources to be utilized. Anthracite and petroleum, quicksilver and zinc, were unknown as treasures within our reach. The rapid extension of possession, government, population, and industry over plains and mountains to the Pacific, which has been effected in a hundred years, is but the type of a conquest and progress which has advanced with equal rapidity in every part of human labor, and nowhere more notably than in the departments of mining and metallurgy. The tables which Dr. Raymond has prepared show that this country has produced during the century ending with 1875, of gold, about 66,680,000 troy ounces, worth about $1,332,700,000; of silver, about 201,300,000 troy ounces, worth about $261,450,000; of quicksilver, 840,000 flasks, or 64,206,000 pounds avoirdupois; of copper, 200,000 tons; of lead, 855,000 tons; of pig-iron, 40,000,000 tons; of anthracite coal, 351,521,423 tons (the ton in all these cases being 2240 pounds avoirdupois); and of petroleum, 76,594,600 barrels. The product of these leading industries for the year 1875 were: gold, $33,400,000; silver, $41,400,000; quicksilver, 53,706 flasks; copper, 15,625 tons; lead, 53,000 tons; pig-iron, 2,108,554 tons; zinc, about 15,000 tons; anthracite, 20,643,509 tons; bituminous coal, about 26,000,000 tons; petroleum, 8,787,506 barrels.

In order that a clear idea may be formed as to the relative position now held by the United States in the world of mining and metallurgy, I have selected the production of coal, which is the main reliance for power of all organized industry, and of iron, which is the chief agent of civilization, as the basis of comparison with other nations, using, so far as coal is concerned, the figures given in the 42d Annual Report of the Philadelphia Board of Trade, for the year 1873*.

	Tons.	Per cent.
Great Britain	127,016,747	46.4
United States	50,512,000	18.4
Germany	45,335,741	16.5
France	17,400,000	6.4
Belgium	17,000,000	6.2
Austria and Hungary	11,000,000	4.0
Russia	1,200,000	0.5
Spain	570,000	0.2
Portugal	18,000	—
Nova Scotia	1,051,567	0.4
Australia	1,000,000	0 4
India	500,000	0.2
Other countries	1,000,000	0.4
Total	273,704,055	100.0

The following estimate, in round numbers, of the world's present production of iron is taken from various sources, and may be considered approximately correct. The figures for Great Britain and France are those of 1874, and the product of the United States for the same year has been taken. For other countries the estimates are principally for 1871 or 1872, except Austria and Hungary, for which the official returns for 1873 have been taken.

The quantities are given in tons of 2,240 pounds:

		Per cent.
Great Britain	5,991,000	45.2
United States	2,401,000	18.1
Germany	1,600,000	12.1
France	1,360,000	10.3
Belgium	570,000	4.3
Austria & Hungary	365,000	2.7
Russia	360,000	2.7
Sweden & Norway	306,000	2.3
Italy	73,000	0.5
Spain	73,000	0.5
Switzerland	7,000	—
Canada	20,000	0.2
South America	50,000	0.4
Japan	9,000	0.1
Asia	40,000	0.3
Africa	25,000	0.2
Australia	10,000	0.1
	13,260,000	100.0

An examination of these tables will serve to show that in the products which measure the manufacturing industry of nations, Great Britain stands first and the United States second on the roll, and there is a clear and almost identical relation between the product of coal and the product of iron. The United States now produces as much coal and iron as Great Britain yielded in 1850. We are thus gaining steadily and surely upon our great progenitor, and in the nature of things, as the population of this country grows, must, before another century rolls around, pass far beyond her possible limits of production, and become the first on the international list, because we have the greatest geographi-

* I wish to acknowledge for these and other figures relating to coal, my obligations to Mr. R. P. Rothwell, who has freely placed at my disposal the very extensive and elaborate compilations of statistics which are to form the basis of an exhaustive paper by his experienced hand on that subject.

cal extent, and our natural resources are upon so vast a scale that all the coal area of all the rest of the world would only occupy one-fourth of the space in which, within our borders, are stored up the reserves of future power.

In a hundred years, we have thus reached a point at which for coal, iron, gold, silver, copper, lead, and zinc, we are independent of the world, with abundant capacity to supply as well our growing wants, as to export these blessings of civilization to other and less favored lands, as soon as our labor and our legislation are adjusted to the conditions which will enable us to compete in foreign markets. One hundred years ago we proclaimed our political independence, and we maintained it by force of arms; we are now in a position to proclaim our industrial and commercial independence, and maintain it by the force of peaceful agencies against friendly competition.

A striking view of this prosperous development is presented by the magnificent mineral collection under the charge of Prof. Blake, in the Government building at the neighboring Exposition—a lection which constitutes the first worthy National Museum of Mining and Metallurgy.

Never was a century of free government celebrated under such favorable conditions; never was free government so justified by the material results it has produced. But let us not conceal from ourselves the fact that mere growth in wealth, mere development in industry, mere increase in population are not the best evidences of national greatness; and unless our progress in art, learning, morals, and religion keeps pace with our material growth we have cause rather for humiliation than for glorification.

"Whatsoever things are true, whatsoever things are honest, whatsoever things are just, whatsoever things are pure, whatsoever things are lovely, whatsoever things are of good report," constitute the real glory of a nation, without which the magnificent material structure which in a century we have reared, will disappear "like the baseless fabric of a vision."

In a hundred years, as I have said, we have reached a point at which, for every one of the minerals and metals named, we are independent of the world, having the capacity to supply our own growing domestic demand, and also to export to foreign lands.

It is not my purpose to trace in detail the steps by which this degree of progress has been achieved. The narration of successive events alone, without any discussion of underlying causes and accompanying effects, would consume far more time than I could command. So far as the leading epochs of the history are concerned, I think they may be fairly summed up in the following mere catalogue:

1. First of all, must be named the erection in Philadelphia, in 1794, of the first steam engine in America. We celebrate this year the centennial anniversary of a greater power than the United States of America—a wider revolution than our War of Independence. It was in 1776 that James Watt presented to the world the perfected steam engine, all the improvements of which since his day are not to be compared with those which he devised upon the rude machines of his predecessors. In one hundred years, the steam engine has transformed the face of the world and affected to its remotest corners the condition of the human race. Few changes have been so profound; not one in history has been so rapid and amazing. With reference to the special subject now under consideration, if I were asked what elements had most to do with the swift progress of our country, I should answer, freedom and the steam engine. But deeper even than any organized declarations or outward forms of freedom lies the influence of the steam engine, which has been from the day of its birth, in spite of laws and dynasties, and all accidents of history, the great emancipator of man.

2. *Gold Mining in the South.*—Already Jefferson, in his *Notes on Virginia*, mentioned the finding of a lump of gold weighing seventeen pennyweights, near the Rappahanock; and, about the beginning of this century, the famous Cabarrus nugget, weighing twenty-eight lbs., was discovered at the Reed Mine, in North Carolina. But the great gold excitement in the south followed the discoveries in Georgia, from 1828 to 1830. The maximum of production (probably never more than $600,000 in any one

year) was from 1828 to 1845, since which time it has declined into insignificance, though a few enterprises, both in hydraulic and quartz mining, are now actively prosecuted.

3. *The Opening of the Anthracite Coal Fields and the use of Anthracite in the Blast Furnace.*—The first of these events practically dates from the year 1820, although some anthracite found its way to market much earlier, and the second from the year 1839. The latter was followed by the development of the vast anthracite iron industry, which has contributed so much to the prosperity of Pennsylvania. The connection between anthracite and civilization was long ago pointed out by Sir Charles Lyell, in connection with his visit to this country, when he observed in this State, and in this very city where we now stand, the strange phenomenon of a vast manufacturing population, dwelling in neat houses and able to keep themselves and their houses clean. This smokeless fuel is a great moral and æsthetic benefactor. It has also proved specially useful in metallurgy—one process at least, the American zinc-oxide manufacture, being impracticable without it; and in war no one will deny its superiority who remembers how our cruisers burning anthracite, and hence not traceable at sea by their smoke, were able to spy and pursue the blockade-runners, whose thick clouds of escaping bituminous smoke betrayed them. Some further observations concerning the production of anthracite, its control and management will be appropriate under another head of my remarks.

4. *The Use of Raw Bituminous Coal in the Blast Furnace.*—This was introduced in 1845.

5. *The Development of the Copper Mines of Lake Superior*, beginning in 1845, and increasing slowly but steadily to 1862, when about eight thousand tons of ingot copper were produced; then declining for some years, to recover in 1868 and 1869 its lost ground, and since the latter year, by reason of the great production of the Calumet and Hecla Mine, to attain an unprecedented yield. The copper production for the United States show that our present product is not far from sixteen thousand tons, of which three-fourths must be credited to the Lake Superior mines.

6. *The Discovery of Gold in California*, in 1848, or rather its rediscovery, since it had been previously known to both the natives and the Jesuit missionaries, and also to hunters and trappers. The wonderful direct and indirect results of this event have been too often the theme of orators, historians and political economists to need a further description from me. Its direct result in the way of mining was the rapid exploration of the Western territories by eager prospectors, and the successive development of placer-mines in nearly all of them. It is difficult to fix the dates of these beginnings; but we may assume with sufficient accuracy that coal mining practically began in Oregon in 1852, in Arizona in 1858, in Colorado in 1859, in Idaho and Montana in 1860. With the completer exploration of the country and the decline of the placer-mines, stampedes have grown less frequent and extensive than in the earlier days. There is scarcely any corner of the country left, except the Black Hills of Dakota, which has not been ransacked sufficiently to show whether it contains extensive and valuable placer deposits; and those districts which presents accumulations of gold in such a way as to offer returns immediately to labor without capital have been already overrun. The principal reliance of our gold-mining industry for the future must be quartz and hydraulic or deep gravel mines. These may be expected to maintain for years to come their present rate of production, if not to increase it. In the gold production there is, it is true, a falling off of late years; but this is to be attributed to the placer-mines.

7. *The Commencement, about* 1851, *of Regular Mining Operations at the New Almaden Quicksilver Mine, in California.*—The production of this metal in the United States has been thus far confined to the State of California; and it will be seen from the production of the New Almaden mine, that it has always furnished a large, though of late a waning, proportion of the grand total for the country.

8. The middle of the nineteenth century was crowded with important events in metallurgy and mining. It was in

1856 that Mr. Bessemer read his paper at the Cheltenham meeting of the British Association for the Advancement of Science, which inaugurated for both continents the age of steel. Within sixty days after that event an experimental Bessemer Converter was in readiness at the furnaces of Cooper & Hewitt, at Phillipsburgh, New Jersey. But the experiment was not carried far enough to demonstrate the value of the newly-proposed process, and it was left to the late John A. Griswold and his associates to introduce and perfect this wonderful method in the United States. I speak more briefly on this point than its far-reaching importance deserves; but in the presence of one whose acquaintance with it is so profound, and whose services in relation to it have been so brilliant as those of our honored President, Mr. Holley, and of so many gentlemen as I see before me who are worthily associated with him in his glorious history, I could afford to be silent altogether.

9. *The Commencement of the Hydraulic Mining Industry.*—The position of the auriferous slates and quartz veins, on the west flank of the Sierra, with the precipitous mountains behind them, and the broad plain before, has favored exceptionally the formation of deep auriferous gravels in which California far exceeds any other known region. And the same topographical features furnish the two other prime requisites of hydraulic mining, namely, an abundant supply of water and a sufficient grade of descent to permit the use of flumes and the escape of tailings. These advantages the keen-witted miners of the Pacific coast were quick to make available; and I think we may set down the invention of hydraulic mining, which occurred, I believe, about 1853, as an epoch in the progress of American mining. It has given us an entirely new and original branch of the art, involving many ingenious hydrodynamic and hydrostatic contrivances; and it has certainly made possible the exploitation of thousands upon thousands of acres of auriferous gravel which could not have been profitably handled in any other way. The mountain torrents of the Sierra, caught on their way to the Pacific, have been forced to pause and do the work of man, The same agencies that buried the gold among the clay and pebbles of the river beds are now made to strip the covering from it and lay it bare again. The hydraulic mines produce, at present, not less than $10,000,000 or $12,000,000 annually; and many enterprises of this kind which have been prosecuted through years of expensive preparation, and are now just beginning to touch their harvests of profits, will add henceforward to the product. I may mention as an illustration, the extensive operations of the North Bloomfield and its two allied companies in California, which have expended in works $3,500,000, and will have six deep tunnels, aggregating over 20,000 feet, and canals supplying 100,000,000 gallons of water daily.

10. We must turn for a moment to the East again, to note the commencement of iron mining at Lake Superior, about the year 1856. The extraordinary pure and rich ores of the upper peninsula of Michigan now find their way, to the extent of a million of tons per annum, in fleets of vessels across the lakes to Cleveland, and are thence distributed to the furnaces of Ohio and Pennsylvania. The similarly pure Missouri ores have built up in like manner their own market.

11. The next great event in the history of American mining was the discovery, in 1859, that the Comstock lode was rich in silver. This opened an era of activity and speculation which has scarcely ceased since that time. Single districts have been subjected to fluctuating experiences, passing from the first enthusiasm through all the stages of hope to reaction and despair; but though the fortunes of each have risen and fallen like the changing tide, it has nearly always been high water somewhere. Thus we have had a succession of favorites in the way of silver-mining districts, each one crowding its predecessor out of the public notice. Of these, the following list includes the most permanently productive: In Nevada, the Unionville, Reese River, Belmont, White Pine, Eureka, Esmeralda, and Pioche districts; in California, the argentiferous district of Inyo County; in Idaho, the Owyhee district; in Utah, the Cottonwood and Bingham districts; in Colorado, the silver districts of Clear Creek, Boulder, and Summit Counties, to which the lat-

est favorite, the San Juan region, may be added. I have named those localities in which mining industry is still active and flourishing. There is a longer and a sadder list, the funereal effect of which I will not intrude upon this festive occasion. But it ought to be remarked, that the apparent failure and abandonment of many districts heretofore does not argue their lack of prospective value. It is, on the contrary, amazing that under the adverse conditions surrounding the industry of mining in regions "remote, unfriended, solitary,"—though not "slow"—so many communities should have succeeded in taking permanent root. Too much is expected of this industry when it is required to supply the lack of labor, food, transportation, government, and the organized support, which in settled societies all the trades and occupations give to each other. Pioneer work is full of peril and of waste; and in view of the wonderful results achieved by our pioneers in mining, it ill becomes us to sneer at the losses and failures which constitute the inevitable cost of such conquests. When the battle has been gloriously won, and the spoils of victory are ours, we do not greatly mourn over the number of bullets that may have been fired in vain.

But through all the vicissitudes of silver mining in other districts, the Comstock mines have maintained their place, an instance of rapid exploitation, and of aggregated wealth of production unexampled in history. Here, too, there have been intervals of failing hope; but a new *bonanza* has always made its appearance before the resources at hand were entirely exhausted; and we have seen extracted from the ores of this one vein, during the past fifteen years, the round sum of $200,000,000 in gold and silver. Dr. Raymond, assumes the product of gold to have been (on the authority of Mr. Hague) about forty per cent. of the entire value. We have, therefore, from the Comstock mines during the period named, $80,000,000 gold, and $120,000,000 silver.

The swift development of these mines, and the active commencement, about the same time, of deep quartz mining operations in California, led to a remarkable progress in mining machinery, and to the perfection of two distinctively American processes. I refer to the California stamp mill and amalgamation process for gold, and the Washoe pan-process for silver. Neither of these is so novel in principle as the hydraulic process of gold mining already mentioned; but both of them have received the peculiar impress of an ingenuity and mechanical skill, partly innate in our national character, and partly the product of the stern pressure of economic necessities. Into the fruitful field of further metallurgical improvements born of our Western mining industry—or adopted by it—such as the Blake rock-breaker, the Stetefeldt roasting furnace, the Brückner cylinder, the Plattner chlorination, and many others less widely known, I cannot enter here. Our people have advanced in this line with headlong energy, and accomplished great results—at great expense. Much, undoubtedly, remains to be done; and it may be hoped that future progress will be equally rapid but less costly. The introduction, three or four years ago, of the smelting processes of Europe for the treatment of the silver ores of the West, is a striking and encouraging instance of the quickness of our mining communities to seize upon the advantages of experience elsewhere, as soon as they are brought to notice. The ignorance which has led to many disasters in such enterprises, was not voluntary or obstinate. Give our people light, and they do not keep their eyes shut. I am assured that already the smelting works of the West present many features of interest and suggestiveness even to the study of our skillful colleagues from abroad.

12. I may be permitted, in closing this imperfect review, to refer to the great improvements in mining machinery, in rock-drilling, in explosives, in the use of gaseous fuel, in the construction and management of blast furnaces, puddling furnaces, rolling mills, and other branches of the iron manufacture, which have crowded upon us during the last ten years. It is impossible here to give even an enumeration of them which shall do them justice. They have been worthily commemorated in many papers before the Institute. With regard to one of them, the Martin process for the manufacture of open-hearth steel, I may speak with some personal satisfaction,

since I had the privilege of introducing it into this country, after studying its merits in 1867 abroad. I am convinced that it has a great future, as the ally, if not the rival, of the Bessemer process.

Returning now to the contemplation of the general field over which we have passed, we may inquire what the Government of the United States has done, with regard to the mining industry. Other nations have elaborate mining codes and bureaus of administration. In comparison with these the meagreness of our governmental supervision of mining is remarkable; yet, in view of the progress I have sketched, may it not be possible that our system has been on the whole the best for us? Certainly a complicated mining code like that of Spain and Mexico, whatever it may have brought to the coffers of the State, seems to have conferred, in centuries of operation, little benefit upon the people.

The common law of England is the foundation of our jurisprudence in this, as in so many other respects. According to that law, as laid down in a noted case in the reign of Elizabeth, all gold or silver ores belonged to the crown, whether in private or public lands; but any ores containing neither gold nor silver belonged to the proprietor of the soil. Apart from the claims of the crown, the property in minerals is, according to the common law, *prima facie* in the owner of the fee of the land, but the property in minerals, or the right to search for them, may be vested in other persons by alienation, prescription, or custom. Since the two latter rights require an origin beyond the time of legal memory, they are practically out of the question in this country. The crown right to the precious metals, as declared in the case referred to, was a survival or remainder of the royalty claimed in ancient times by the sovereign over all minerals. This sweeping claim, born of the despotisms of the Orient and made the subject of much conflict among emperors, feudal lords, and municipal authorities during the middle ages, dwindled at last till it covered only gold and silver. But it disappeared entirely from English America, for the simple reason that there was no private land ownership in this country, and the sovereign of England claimed, by right of discovery, soil and metals alike, barring only the Indian title, which it was his exclusive privilege (or that of his authorized representatives or grantees) to extinguish, After the Revolution, the United States succeeded to the rights of the British crown, and by the treaty of peace and the subsequent cessions by the different States of their colonial claims upon the public lands, the federal government became possessed of a vast domain over which, after extinguishing the Indian title, it had complete control. In the territories subsequently acquired from France and Spain, the United States assumed the rights and obligations of those sovereigns; and this circumstance, particularly in the adjustment of Spanish mineral and agricultural grants, has caused some apparent variations from the general policy. But it is sufficiently accurate to say that at the present time, throughout the country, the owner of the fee, or the party who has obtained from him by lease or purchase the mineral right, has supreme control. The mining legislation of the United States, therefore, is simply a part of the administration of the public lands; and for this reason it is executed by the Commissioner of the General Land Office.

In 1807 an act was passed, relating primarily to the lead-bearing lands of Illinois. They were ordered to be reserved from sale, and leased to miners by the war department. The leases covered tracts at first three miles square (afterward reduced to one mile), and bound the lessee to work the mines with due diligence and return to the United States 6 per cent. of all the ores raised. "No leases were issued under this law," says Professor Whitney, "until 1822, and but a small quantity of lead was raised, previous to 1826, from which time the production began to increase rapidly. For a few years the rents were paid with tolerably regularity; but, after 1834, in consequence of the immense number of illegal entries of mineral land at the Wisconsin Land Office, the smelters and miners refused to make any further payments, and the government was entirely unable to collect them. After much trouble and expense, it was, in 1847 finally concluded that the only way was to sell the mineral land, and do away with all reserves of lead or any

other metal, since they had only been a source of embarrassment to the department."

Meanwhile, by a forced construction (afterwards declared invalid) of the same act, hundreds of leases were granted to speculators in the Lake Superior copper region, which was, from 1843 to 1846, the scene of wild and baseless excitement. The bubble burst during the latter year; the issue of permits and leases was suspended as illegal, and the act of 1847, authorizing the sale of the mineral lands, and a geological survey of the district, laid the foundation of a more substantial prosperity.

This policy of selling the mineral lands has been that of the government ever since. But it has necessarily been modified in the West by the peculiar circumstances under which that region has been settled. Before lands can be sold they must be surveyed; and before they can be sold as mineral lands, their mineral-bearing character must be ascertained. Our miners and explorers overran and occupied the Pacific slope in advance of the public surveys. They built cities that were not shown on any map; they cut timber, turned water-courses, dug canals, tunneled mountains, bought and sold their rights to these improvements under laws established by themselves, and enforced by public sentiment only. For nearly twenty years the government looked on, without asserting its dominant ownership of the public lands; and when by the acts of 1866, 1870, and 1872, and other minor enactments, a general system was created, it was necessary to recognize as far as possible the rights which had grown up by general consent, and to seek only to give to them certainty, practical uniformity, and reasonable limitations. It is not my purpose to discuss in detail the mining laws of the United States, or to trace the curiously complicated origins of the local customs on which they are largely based. Suffice it to say that the system recognizes the English common law principle, that the mineral right passes with the fee to the lands; so that, in the words of the commissioner (July 10th, 1873), "all mineral deposits, discovered upon land, after United States patent therefor has issued to a party claiming under the laws regulating the disposal of agricultural lands, pass with the patent, and the Land Office has no further jurisdiction in the premises."

But the principle is also recognized that the mineral right may be separated from the fee by the owner, whether he be an individual or the United States; and this principle is curiously applied in the form of patents for mining claims upon lodes, which, following the form of the possessory title, grant to the patentee the right to follow all veins, the top or apex of which lies within the exterior boundaries of his claim, downward to any depth, though they pass under the surface of the land adjoining.

As the size and the price per acre of the tracts sold under the agricultural laws are different from those to which the mining laws apply, and as, under the homestead law, a certain amount of agricultural land may be obtained without any payment, it is evident, that no known mineral deposits can be acquired under the agricultural laws; and this reservation is enforced both in the preliminary proceedings and in the patents finally issued under those laws.

With regard to the mineral lands, however, it is certain that the patent for a claim carries with it both the fee of the land and also a mineral right, though not the same mineral right as is contemplated by the common law; since it is enlarged on the one hand by the permission to follow mineral deposits beneath the surface of adjoining land, and limited on the other hand by the operation of the same permission in favor of the adjoining owner. The latter limitation is incorporated in agricultural patents also, and may become operative whenever they adjoin mining patents.

Previous to the application for a patent, the law permits free exploration and mining upon the public lands to all citizens and those who have declared their intention to become such. The rights of this class of miners, under what is known as the possessory title, are regulated by local laws and customs, subject only to a few simple conditions, which the United States enforces upon all, and which chiefly concern the maximum size of individual claims, the definite character of their boundaries and landmarks, and a certain quantity of labor which must be bestowed upon them annually, in order

to maintain possession. I will not pause to state the different features which these conditions present for lode and placer claims. It is sufficient to say that the miner, conforming to them, and thus maintaining his possessory title, may, after a certain expenditure, and upon due application, survey, and advertisement, in the absence of any valid opposing claim, perfect his purchase from the Government, receive his patent, and be thereafter free from the necessity of performing any given annual amount of labor to hold his claim. There are features in the present law concerning the rights of prospecting tunnels which seem both obscure and unwise; and some serious questions remain to be settled as to the precise meaning of the law in these and other respects; but these we must pass by.

Looking at the legislation on this subject as a whole, we see that it is confined to one department—that of title. The whole system is devised to facilitate the purchase of the mines by citizens. They are freely permitted to work them experimentally, but it is made their interest to buy them. No inspection, no police regulation, no technical control, is exercised by the Government.

Turning to the State and Territorial Legislatures, we find that they have, in some cases, provided for inspecting mines, in the interest of the safety of workmen. Perhaps the best law of this kind is that of Pennsylvania, in which State the peculiar perils of coal-mining have forced the Legislature to take measures of protection. But we find nowhere such a technical control of mining as is exhibited in many European States, where the government requires of the miner that he shall not waste wantonly or ignorantly the resources which, once exhausted, will never grow again. Our people waste as much as they like, and no one interferes. Admitting that this is an evil, it still remains a matter of doubt how far, under the circumstances of our particular case, the supervision of authority could remedy it. For my own part, though inclined to restrict as far as possible the functions of government, I am not disposed to say that for so great an end as the conservation of the mineral wealth of the country, it may not properly enforce some measures of economy, with as good right as it may forbid the reckless waste of timber or the slaughter of game out of season. But, in our nation, at least, governmental interference is the last resort, and a poor substitute for other causes, which, in the atmosphere of freedom and intelligence, ought to be effective. We are, perhaps, in our material career, as a nation, like the young man who has "sown his wild oats," and now, by mature reflection, and the lessons of experience, is likely to be better restrained than by the hand of parental authority.

Permit me, in drawing my remarks to a close, to suggest two agencies which seem to me to be co-operating already, and to open still wider future prospect, for the steady, social and economical improvement of our mining and metallurgical industry.

The first of these is the spread of knowledge on these subjects throughout the country. Under this head we must recognize the great importance of that series of explorations of our great Western domain, which was recommended by Mr. Lincoln, with sublime faith in the salvation of his country, in the midst of the civil war, and which has been, by the liberality of the Government, prosecuted under various departments ever since. I need hardly make special mention, in addition, of the reports of the Commissioner of Mining Statistics, which have appeared annually since 1866, and have reflected upon our own community the light of the gathered technical knowledge of the world, while they have in turn exhibited to the world the resources and progress of America. Such works as these, together with the technical periodicals and the occasional volumes, translated or original, which have come from the American press, have contributed already a great deal to the education of our mining communities. The government has not done too much in this direction; but it seems to me that it should continue this most necessary and proper work in a more systematic and uniform way. There ought to be no conflict of authorities, no duplication of work, no unnecessary expenditure of labor and money in the face of a task so great.

Next in order, I may rank the influence of the technical schools. The num-

ber of these has rapidly increased during the past ten years; and I venture to say that many of them compare favorably, in theoretical instruction at least, and several of them in the apparatus of instruction, with the famous schools of the old world. The Massachusetts Institute of Technology, at Boston; the School of Mines of Columbia College, at New York; the Sheffield Scientific School of Yale College, at New Haven; the Stevens Institute of Technology, at Hoboken; the Pardee Scientific Department of Lafayette College, at Easton; the excellent school at Rutgers College, under the direction of Prof. Cook; the new Scientific Department of the College of New Jersey; the School of Mining and Metallurgy of Lehigh University, at Bethlehem; the School of Mining and Practical Geology of Harvard University, at Cambridge; the Scientific Department of the University of Pennsylvania, in this city; the School of Mines of Michigan University, at Ann Arbor; the Missouri School of Mines and Metallurgy, at Rolla; the Polytechnic Department of Washington University at St. Louis; and the similar department of the University of California, at Oakland; and perhaps some others which I have omitted to name—this is a list of schools for instruction in the sciences involved in mining and metallurgical practice, of which we need not be ashamed. What our schools undoubtedly need, is a more intimate relation with practice. But this theme I need not touch. It has been ably and amply discussed at the joint meeting last night of the two bodies most fully aware of all its bearings.

One more agency of the speed of technical knowledge deserves special mention. I refer to the influence of societies like the Institute of Mining Engineers. The five years activity of this Institute has impressed upon the professions which it represents a spirit of union, an enthusiasm of progress, a mutual recognition of the claims of theory and practice, which cannot be too highly estimated. Perfect our schools as much as we may, the association of the young engineer with experienced engineers, the contact of his mind with mature minds, their recognition of his merit, their correction of his errors, constitute the necessary supplement to the school-training. The average man, at least, should not be left to wrestle with his professional career alone. He will make better progress and take more pleasure in it, if he calls to his aid the element of social sympathy, and the intellectual reinforcement expressed in the proverb, "many heads are better than one."

One further consideration, and I have done. The effect of growing intelligence and knowledge in improving our methods of industry would come short of some great ends if it operated only through the self-interest of the individual. Many reforms are beyond the power of the individual; some are not even to his interest. Thus the miner under a possessory title on a gold-bearing quartz vein in Colorado may know that with a greater investment of capital he could manage to reduce his losses of gold in extraction; but the capital may be wanting; or, he may know that by robbing the mine of its richest ores only, and allowing it to cave, he is probably distroying more valuable resources than he utilizes; but the mine is only temporarily his, and he prefers quick gains to permanent ones. So long as the anthracite lands of Pennsylvania were leased to countless small operators, who paid royalty only on the coal which they sent to market, it was useless to explain to them that they wasted a third of the coal in the ground, and another third in the breaker, or that they ruined thousands of acres of coal-beds, overlying those which they recklessly worked. If there were no natural remedy for this wicked waste of the reserved force upon which the future prosperity and comfort of mankind depend, it would be the highest duty of Government promptly to take into its own hands the direction and management of the mines of coal which society holds in trust for the future; but already it is easy to detect the operation of a new social law developed within the memory of man, yet the fruit of the preparation of the ages during which society has been slowly built up, and matured into its present form and conditions.

To the philosophic observer, the controlling law which runs through the whole history of man, down to the present century, is the law of dispersion, diffusion, distribution, the centrifugal

social force, so to speak, which by its irresistible power has tended not merely to scatter mankind over the face of the habitable globe, but through what are termed civilizing and Christianizing agencies to place communities and individuals upon the common plane of equal rights in the domain of nature and before the law.

From the time of the confusion of tongues at the tower of Babel, through the long history of the early Oriental Empires, which reduced society to the rule of order and then broke up into fragmentary political organizations, retaining, nevertheless, the principles of cohesion acquired by bitter experience; through the Greek and Roman imperial political stuctures upon which were ingrafted the civilization and the religion which their downfall made the common heritage of the northern barbarians who came for destruction, but were themselves transformed into the apostles of a more liberal and enlightened social organization, this law of dispersion has never ceased to exercise its power and its supremacy. The very inventions of man are only so many proofs of the unceasing operation of this law. In warfare, gunpowder and firearms merely enlarged the area over which it was possible to carry on military operations; the magnetic compass only widened the field of commerce; the printing-press and the telegraph are merely agencies for the diffusion of thought; the steam engine is but a means whereby it becomes possible to establish local industries in every part of the habitable globe; and the canal and the railway are essentially distributors of the products and the wealth of the human race.

Although there is an impression abroad that this age is one of growing concentration of property, no man can study the history and the facts of the development of society without coming to the conclusion that at no period has there been so general and equal a distribution of rights and property as in the present age. The destruction of the feudal system was, in reality, the establishment of a new and better theory, in regard to the ownership of land, which has borne its legitimate fruits in the subdivision of estates in France, through the convulsions of a revolution; in the more general distribution of landed property in Germany, and in that steady, remarkable, and successful agitation in England, which is now showing its results in the limitation of entail, the simplification of transfer, the enlargement of the suffrage, and the acquisition of small freeholds, whereby political power is being slowly but surely transferred from the great landholders to the middle classes of the most powerful and compact political organization which the world has ever seen.

While, then, there is thus an unmistakable progress in the world towards a juster and more general distribution of the control of the resources of nature and of the fruits of human industry, the present century has, undoubtedly, developed a new and remarkable centralizing tendency, which might be denominated the centripetal industrial force. I speak of the application of the corporate principle to the management of industrial enterprises, producing a concentration of property and management through the diffusion of ownership. Under the corporate system, the number of owners may be unlimited, but the management is necessarily confined to a few hands. It is the political idea of representation applied to industrial enterprises; it is the common wealth in its industrial, and not its political sense, which is concentrated for the material wants and progress of the human race. Now, this law of universal ownership, under limited management, heretofore applied with marked success during the latter half of the present century to great manufacturing establishments in this country, and of late in Europe, and of necessity to railroads everywhere, has at length, by slow but irresistible steps, taken possession of the great mining enterprises of the United States, and to-day has its strongest and most interesting development in the anthracite coal region, which may be said to be monopolized by six great corporations, administered by a very small number of able officers, representing a vast body of owners who rely upon steady, but not excessive, dividends for their support. It is the fashion to denounce these corporations as monopolizers, but it is only the thoughtless, who do not investigate below the surface, who take this view of what is

really the most interesting and suggestive application in our day of a powerful and irresistible force originating in the very heart of the social fabric. The monopoly is not the monopoly of ownership, for everybody is free to buy and sell, and there is no day when a man with money may not, at its value, procure a share in these enterprises. And no one familiar with business will pretend that the profits have been out of proportion to the cost and the risk of the undertakings, and no more conclusive answer to any complaint on the score of monopoly can be made, than that to-day the shares in these corporations, in many cases, are selling below the original money cost. These corporations are, in fact, not the creators, but the outgrowth of a new and beneficent principle, which has begun to assert itself in society, and will continue to grow in power until the end of time. This principle is the practical association of diffused capital, through the agency of corporate organization, with labor, for the promotion of economy, for the improvement of processes, and for the general welfare of mankind.

The capital is derived from innumerable sources, just as the little rills, finally, through streams and rivers, constitute the great ocean. The laborer himself may thus be the capitalist, and the capitalist may thus be the laborer, each taking his share of that portion of the fund which is appropriated to labor and to capital, and often in a double capacity taking a share from both.

In its perfect and ultimate development it embodies the Christian idea of "having all things in common," yet "rendering unto Cæsar the things that are Cæsar's."

The rate of profit which may be derived from these great enterprises, subject as they are to the scrutiny, criticism, and judgment of the public, in an age when nothing escapes notice, and all rights and property are virtually subordinated to the popular will, can never be excessive, for two reasons: on the one side the public will inevitably demand lower prices for an article of primary consequence in every household, and these corporations, creatures of the public will as they are, could not successfully resist such a demand, based upon excessive or unreasonable profits. On the other hand, whenever the dividends rise above a reasonable rate of compensation, the laborers engaged in the production of coal, from whom these profits cannot be concealed, will justly claim, and rightfully secure, a larger share of the fruits of their labor. The checks upon any unreasonable exercise of the power conferred by the ownership under limited management of the anthracite coal-fields, are in reality so powerful that the public have nothing to fear from this cause, but the corporations have rather reason to dread that they may not have justice at the hands of the public and the working classes. This justice they can only hope to secure by the wisest, best, and most economical management and administration of the property they control, and whatever profits they may hereafter derive and be allowed to divide among the owners, will be rather due to the economies which they may be able to introduce, whereby the article is furnished at the lowest possible rate, than to any fancied monopoly which they may have in the coal itself, or in its transportation to market.

Already, by the application of adequate capital, guided by the largest experience and the highest technical skill, the anthracite coal-mines, from being worked in a wasteful and extravagant manner, are being rapidly put in the best possible shape for the economical delivery of coal at the surface, and for the preservation of every portion of the store upon which the future value of the property must depend. But besides economy in mining and care in preserving, there must be regularity and stability in the operations of the mine. There can be no real profit where these operations are subject to constant interruption, caused by strikes or other artificial impediments. The loss of interest on the plant at the mines, and in the lines of transportation caused by any serious stoppage to the works, would, of itself, be sufficient to render investments of this kind unprofitable. Hence the out-put must be regulated and proportioned to the wants of the market. But this regulation must be continuous and not spasmodic. To enable this to be done, large stocks of

coal must necessarily be kept on hand, in order that any sudden demand may be properly met without any serious increase in price; and in dull times the accumulation and restoration of the stocks will give steady employment to the miners, to whose families any cessation of work is a calamity of the most serious character, and to society an unmitigated evil. To insure continuous operations, the best relations must exist between the corporate owners and the laborers in their employ. It is notorious that throughout the coal regions these relations have been of the most unsatisfactory character, resulting, at often-recurring intervals, in strikes and lock-outs, which have no redeeming feature, but, on the contrary, have raised the price of coal to the consumer, have impaired the dividends of the owners, and have reduced the working men and their families to a condition of suffering and demoralization, appalling to every well-wisher of his race. It is fortunate, therefore, that the interests of all classes concur in the prevention of these destructive and demoralizing collisions, and that the owners of the property, for their own self-protection, will be driven to remove the causes which have produced them. It is idle for them to expend their capital for the best machinery, for the highest skill, for the most economical transportation, unless they can, at the same time, insure a continuous production from a contented laboring population.

This they have it in their power to do. If the same spirit of sacrifices, which has sent out our missionaries into every heathen land, had been shown in the coal regions, and the same efforts had been made to establish and maintain the school house, the church, and above all the Sunday school, which have borne such fruits elsewhere in this broad land; if the hospital for the sick, and the comfortable refuge for the unfortunate had been carefully provided; if reading rooms and night schools, and rational places of amusement had, from the outset, been maintained for a growing and restless population, the coal regions to-day might have been a paradise upon earth instead of a disgrace to civilization. And here it is that this new power of concentrated management can exert itself with sure and absolute success. The appropriation of a few cents per ton on the coal mined to the work of improving the moral and intellectual conditions of the miners and their families will, in a time incredibly short, change the whole face of society in the coal regions.

To be effective, however, this consecration of a fixed amount on each ton of coal sent to the market must be as absolute and final as that portion of the proceeds which is devoted to pumping the mines, or driving the gangways. It must not come from grace, but from a sence of duty involved in the ownership of property, and dictated by a wise regard for its preservation and permanent value. Even if this percentage were added to the price of the coal the addition would not be grudged by the public; but in fact no such addition could possibly occur, as there is no surer way of promoting economy in the cost of production than by improving the social condition, the self-respect, and the intelligence of those who are engaged in the work of production, which thus becomes continuous and systematic. Until the great companies thus recognize the duties, the responsibilities, and the opportunities for good, which are offered by the new social development which has rendered their existence a necessity, as well as a possibility, they must not complain that they are regarded with distrust, and as enemies, both by the public which consumes there products and by the working classes who see in them only grasping employers without a conscience. What individual owners could not do, it is easy for these great companies to put in practice; but the effort must be as earnest and serious as is the business of producing the coal and getting it to market. The very best talent must be secured for the organization and management of the various agencies necessary for the moral, intellectual, and social improvement of the working classes, who must be themselves associated in the administration of the fund created and expended for their benefit. Five cents per ton would produce an annual revenue of over $1,000,000 applicable to this necessary and noble use, and five years of its intelligent and conscientious administration would convert what in some regions has been aptly termed a "hell upon earth" into a terrestrial paradise, which

would be the pride and the glory of the new world.

What more fitting celebration of the Centennial year of American Independence could be possibly suggested or devised, or how could the advent of the incoming century be better signalized, than by the foundation on the part of the great anthracite coal companies of a new department in their administration for the moral, mental, social, and physical improvement of the workingmen and their families, and by the appropriation of a fixed charge on coal for this purpose. Let each of them select a well-paid and competent agent to devote himself to this work; let the various agencies be widely organized and surely perfected, and there will be realized one of the greatest triumphs of that gospel which proclaimed, "Peace on earth, and good will towards men." The example thus set will soon extend itself to other industries, and to every branch of business which can adapt the corporate principle of the concentration of management through diffusion of ownership, the result of which will be that the strange phenomenon, now felt throughout the civilized world, of a general glut of products in the face of general want of them, will never again be witnessed; because, when the working classes, through the diviner agencies of Christian effort, shall have constant employment and adequate compensation, the sure results of general enlightenment and a cultivated conscience in the use of property, the power of consumption, now so far in arrear, will surely overtake the power of production, and re-establish the equation which nature intended to subsist between them. Thus may be realized that Christian commonwealth which has been the dream of the patriot, the philanthropist, and the statesman, in all ages, in which every man who is willing to work shall find employment, and in which the products of industry will be so distributed that every man shall feel that he has received his fair share of them; in which there will be neither abject and hopeless poverty on the one hand, nor superfluous riches on the other, because the problem of how to distribute capital through the concentration of management will have been fully solved, and be thoroughly comprehended by all classes in the community; in which the quaint questions put by Sir Thomas More, three hundred and sixty years ago, will at length have been answered, and his suggestive commentary thereon have lost its significance:

"Is not that government both unjust and ungrateful, that is so prodigal of its favors to those that are called gentlemen or goldsmiths, or such others who are idle, or live either by flattery, or by contriving the arts of vain pleasure; and on the other hand takes no care of those of a meaner sort, such as ploughmen, colliers, and smiths, without whom it could not subsist?

"But after the public has reaped all the advantages of their service, and they come to be oppressed with age, sickness, and want, all their labors, and the good they have done is forgotten, and all the recompense given them is, that they are left to die in great misery. The richer sort are often endeavoring to bring the hire of laborers lower, not only by their fraudulent practices, but by the laws which they procure to be made to this effect, so that though it is a thing most unjust in itself to give such small rewards to those who deserve so well of the public, yet they have given those hardships the name and color of justice, by procuring laws to be made for regulating them."

Although I quote from the *Utopia*, let it not be supposed that there is anything Utopian or impracticable in the proposition which I have advanced. It seems to me to be the next great step to be taken for the amelioration of the condition of mankind. The law of diffusion which thus far has governed the progress of the human race toward a higher and better plane of civilization, has at length made an effective lodgment in the domain of capital, whereby it is rendered capable of infinite division without impairing, but in effect improving, the economy and force of its administration. The reproach that "corporations have no souls," must, and will, next be removed, so soon as the beneficent possibilities inherent in these agencies shall be generally recognized, and those who are called to the management shall see that because capital is aggregated, the primary law on which all property rests, that it is a trust to be administered for the public good, loses none of its force,

but can, in reality, only assert itself in all its vigor when concentrated management is brought to bear upon great aggregations of capital. Man did not become a "living soul" until God breathed into him the breath of life. So corporations are mere machines until they are inspired by the associated conscience of society, to which they can give ready and effective expression, and I look for this expression first from the great coal companies, because their property and their peculiar organizations make it easy as well as profitable for them to put in practice the fundamental idea, that a fixed portion of the proceeds of industry should be invariably devoted to the social improvement of those who labor directly for its development.

If the seed here dropped should take root, as I pray and believe it will, then indeed will the country and the world have reason to rejoice at the industrial development of the last hundred years, and the celebration of this Centennial be the dawn of a better day for the patient sons of toil, who, let it be confessed, with all frankness and humility, have not yet been endowed with their fair share of the good things of this goodly earth.

THE MANUFACTURE AND ENDURANCE OF IRON RAILS.*

By W. E. C. COXE.

From "Iron."

In 1857 the Philadelphia and Reading Railroad Company, whose main line extended from Philadelphia to Pottsville, Pennsylvania, with branches into the coal regions of Schuylkill County, made a contract with the Fairmount Rolling Mill, at Philadelphia, for the re-rolling of some 4,000 tons of iron rails. The essential features of the agreement were, that the old rails should be piled with puddled iron, and rolled into flats for the rail-pile; which latter was to be of a section 7 inches square, and, after being heated, and reduced by rolling to a bloom of a section about 5 inches by 6 inches, was to be reheated, before being finished into the rail of the T pattern, 4 inches high, weighing 64 lbs. per yard. Great care was exercised in the execution of this contract, and the rails being distributed over all parts of the road gave general satisfaction by their excellent wear. Five years afterward, the principal proprietor and manager of the Fairmount rolling mill was elected president of the Reading Railroad, and very many of the rails made under his supervision were still in use in the tracks of the company of which he had just assumed the management. His first efforts were therefore directed to the procuring of more rails of the same quality wherewith to replace those worn out. Here he encountered some trouble, makers refusing to bid because of the details in the specification; the required reheating being the objectionable feature, for which it was generally intimated they would not be sufficiently remunerated for the increased labor, extra coal consumed, and the changes necessary from the established methods of working. Most of the new rails were therefore bought, and the old rails re-rolled, without regard to any particulars as to the manner of piling, heating, &c. Each manufacturer furnished what he deemed the best article possible for the money. As a consequence, rails of all imaginable grades were placed in the tracks, some giving out in six weeks under a heavy traffic, the majority within a year, and very few lasting over two or three years.

So great was the dissatisfaction with the character of the iron rails the company were able to obtain, that in the latter part of 1866 they determined to erect a rolling mill and manufacture for themselves. Bessemer steel rails were then coming into this country from England in small quantities at very high prices, and their use at that time was question-

* Read before the June meeting of the American Institute of Mining Engineers.

able ; but their introduction was considered, and in planning for the mill, engines and trains were adopted of sufficient size and strength for the rolling of steel. Ground was broken at Reading in the spring of 1867, and the first rail turned out in March, 1868. It was the intention from the inception of this project to make a rail of the very first quality, and, whilst it was not believed they could be made for a less cost than the market price of an ordinary rail, the profit or gain would be the enhanced endurance of the product. The result has fully justified the wisdom of the policy, and the expenditure of the plant has been more than returned by the dollars saved in becoming their own manufacturers.

The Reading Railroad at the expiration of 1875 owned, leased and controlled 1550 miles of track and sidings. The transport department requires for its business 404 locomotive engines ; 14,975 eight and four-wheeled coal cars; 3,520 eight-wheeled and 328 four-wheeled freight cars ; and 310 passenger cars. In addition, the roadway department has in use for construction and repairs 687 four-wheeled cars. The class of traffic is peculiar, about 60 per cent. being coal, 34 per cent. freight, and 6 per cent. passenger ; the nature of the traffic being especially destructive to the permanent way.

The rolling mill constructed by the company consists of twelve single puddling furnaces, with a yearly capacity of 6500 tons of puddled bars; eight heating furnaces; and two reheating furnaces capable of furnishing 20,000 gross tons of finished rails annually. It is more especially a re-rolling mill. The mode adopted for making the rails was to work about two-thirds of old rails with one-third of new or puddled iron. Three pieces of old rails are piled on two layers of puddled iron, and heated and rolled into 3 inches and 4½ inches by 1 inch flats; these form the body of the pile, being piled so as to break joints 7 inches high. The headpiece is rolled from a 9-inch square pile of these same flats heated and rolled into a slab 9 inches wide by 2 inches thick, forming about 22 per cent. of the whole pile. The rail pile thus made up to a section 9 inches square is rolled in three-high 23-inch rolls, until reduced in six passes to a bloom 7 inches wide on the base, 5 inches high and 5 inches wide on the top; the bloom would somewhat naturally assume this shape in the course of reduction, but it was more particularly given to distinguish the head part of the bloom from the flange. The bloom is then carried hot to a reheating furnace, and wash heated, preparatory to the final rolling to the finished rail, which is done on a two-high 23-inch train in six passes, a total of twelve passes from the 9-inch pile to the rail 4½ inches high.

The use of the puddled iron with the old rails prevents the dryness inherent generally in re-worked iron, and insures with the wash heating better welds. The bloom is kept in the reheating furnace a sufficient time—say fifteen minutes—to bring it up to a good welding heat. The bloom going quite hot to the finishing rolls is completely welded in the first three passes, and, as the rolling is done in one direction only, the rolls being two-high, it is believed the cinder is nearly all expelled, instead of being retained to some extent by being chased backward and forward, as would be done by rolling in both directions on three-high rolls. After the bloom is thoroughly cemented the cinder being no longer essential, it is well not to retain it in the rail.

It is very evident in the rolling on the two-high train that the rail comes from the last or finishing pass colder than it would if rolled on three-high rolls, from the fact of more time being required for the rolling in carrying over the rolls instead of passing through a groove, and thus considerable heat is lost. The colder the rail is rolled in the last few passes the denser and harder will be the metal. In this way an extremely sound rail is obtained, with a good wearing surface. All the rails are stamped or embossed with the year of their manufacture, and as they are placed in the tracks the month is also stamped upon them. Old rails when worn out or used up are returned at once to the mill, and from the stamp upon each rail we get the date of its birth, and, knowing the time of death from its return, we can compute the life of the rail. In the annual reports of the president of the Reading Railroad Company, since 1868,

will be seen a statement of the wear of the rails manufactured by the company. From this we learn that out of 9,000 tons of rails made and placed in the tracks in 1868, the first year the rolling mill was operated, only 4,500 tons, or 50 per cent. had been returned at the close of the year 1875 as worn out, leaving 50 per cent. as still in nse. In 1869, the second year, 17,000 tons were rolled and put in the road, out of which but 4000 tons or 24 per cent. have been condemned and returned for rolling, leaving 76 per cent. still in use. As it is probable that some of the first two years' make, although too much worn to be of service in the main tracks, were sufficiently good to be placed in the sidings, instead of being sent back to the mill, no estimate is made of the tonnage carried; but, passing to the third year, 1870, the product being 17,500 tons, we find only 3,000 tons or 17 per cent. have been condemned as worn out, and taken from the tracks, leaving 83 per cent. of this year's make still doing service after six years' use, having carried some 50,000,000 gross tons.

It should here be stated that at the expiration of the year just mentioned the weight of the rail was increased from 64 to 68 lb. per yard, more metal being put in the head with the expectation of making it still more lasting. The product of 1871 was 19,000 tons, 92 per cent. of which can now be found in tolerable condition, after having borne five years' traffic; and of the product, 20,000 tons, of 1872, only 6½ per cent. have been worn out under a tonnage of 35,000,000. Since 1872 the make has averaged 15,000 tons per annum, but owing to the remarkable endurance of the rails previously made all the new rails manufactured in 1873, 1874, and 1875, have not been laid in the track, and the percentages of removals are not quite so accurate as those already mentioned. This generally would seem to show the uniform excellence and durability of the rails turned out by the process described.

Late in 1869 it was decided to make some particular tests of rails manufactured in the usual way, with the exception of leaving the old rails out of the headpiece, and substituting some special brands of pig iron, worked alone for this purpose. In January, 1870, these rails were placed in the down track of the main line above Reading, near the rolling mill, where they would be required to carry most of the immense tonnage from the coal regions, and where they could be frequently observed by the writer, and their wear carefully noted.

The rolling of some of the piles for the heads on edge so as to bring the welds vertical instead of horizontal in the finished rail was for the purpose of comparing the two methods. In the horizontal piling most of the failures arise from lamination. The best results followed from the edge rolling. The welds, although vertical in the heads of the finished rails, are in practice rolled horizontally from the manner of the rail going through the last three passes on its side, the vertical pressure more thoroughly welding the head. Twelve varieties of pig iron were selected for trial, nine from the Schuylkill Valley, two from the Lehigh, and one from the Susquehanna. Pieces were taken from the different kinds after being puddled, and once reworked, and tested for tensile strength, the maximum being 66,000 lbs. and the minimum 45,000 lbs. to the square inch. They were divided into three classes: the neutral iron, with tendency to cold-shortness, gave an average tensile strength of 63,200 lbs., the red-short 60,700 lbs., and the cold-short 62,500 lbs. These were again arranged in two lots, those with heads rolled flat, and those with heads rolled vertical, and tonnage, including weight of engines and cars, actually carried by each kind before it was worn out was as follows:

Kinds of Iron.	Rails with heads rolled flat.	Rails with heads rolled vertical.
Red-short average.....	26,959,808 tons.	22,819,300 tons.
Neutral average.....	22,412,593 "	28,789,361 "
Cold-short average.....	26,645,538 "	33,472,600 "
Total average.	25,324,348 "	30,040,670 "

From this we gather that the cold-short irons rolled on edge show on the average the most endurance. The parcel of rails doing the best was removed

after six years of service, during which time 55,000,000 tons passed over them. One of these rails carried over 56,000,000 tons, and was taken from the tracks before being absolutely worn out, to be placed on exhibition at the Centennial Exposition. The hard, fine-grained cold-short irons are more durable than the softer and stronger fibrous irons of a red-short nature. The cold-short irons appear to give the best welds, and the stronger they are the better. The iron in the heads of the rails bearing the maximum tonnage was from a blast-furnace in the vicinity of Reading, and was smelted from a mixture of 60 per cent. East Pennsylvania hæmatites, 25 per cent. Tilly Foster, and 15 per cent. East Pennsylvania magnetic ores. The analysis of this head iron gave:

Phosphorus	.422
Silica	.392
Sulphur	.032
Manganese	.164
Carbon	.027
Iron	98 963
Total	100.000

In the same track with these experimental bars were laid some rails with the heads formed of a solid hammered charcoal bloom, with the expectation that being without welds they would show a wear equal almost to steel, but they gave out under a tonnage of 28,000,000. As the iron was too soft from lack of sufficient rolling, they mashed out in spots under the heavy traffic. Puddled steel-headed rails have not done much better from the same causes. Some excellent results were obtained from steel-headed rails, made by welding Bessemer and Siemens-Martin or open-hearth steel slabs on to an iron base, but, as the purpose of this paper was to deal with iron rather than steel, inquiry in this line will not be extended further.

Whilst admitting the vast superiority of steel for rails required to stand a very heavy traffic, iron, if carefully selected and properly manufactured, has a capacity for which it seldom gets credit. At the present time it is possible to make iron rails by the method described at considerably less than the price of steel rails, and as a matter of economy it is of vast importance to roads with an ordinary traffic to consider whether they shall substitute steel for their old iron rails, disposing of the latter at a sacrifice, or have them re-rolled by the process adopted by the Philadelphia and Reading Railroad Company.

THE MANUFACTURE OF STEEL AND MODE OF WORKING IT.

By M. CHERNOFF.

From "The Engineer."

Steel, as generally used in the arts, is a combination of iron and carbon. The purer these elements in steel the higher are its qualities. The best steel that has ever been made in any age or country is, without question, "boulat" (the sabre steel of the Tartars). The special qualities of boulat, and especially the markings appearing on its surface, have sent many investigators on a wrong scent; all thought to find the extraordinary qualities of this steel in some special mixtures. Careful analyses have been made, but, to the surprise of all, nothing has been found competent to explain the presence of the characteristic veining. Inasmuch as the veining of boulat is closely connected with its quality, it was attempted to find substances which, being melted with the steel, would produce the markings required. Steel was melted with various metals, with platinum, silver, and so on, and veinings were, no doubt, produced; but in the first place, they were far from having the same regularity and beauty, and secondly, as well as chiefly, the steel produced was always inferior to boulat. The peculiarity of the veining of boulat lies also in this, that if you heat a good specimen of the steel with clearly marked veining to a bright red heat, and then allow it to cool, it will be impossible to restore the markings, no matter how

long you treat the surfaces with acid. The veining, on the other hand, produced by the mixture of metals never disappears, however much the steel may be heated. But if the piece of boulat in which the veining has disappeared be melted again, then, if certain conditions in the cooling of the ingot are observed, the veining appears again, though of a somewhat different design; and in this manner it is possible to produce or annihilate the pattern several times. The investigations of Anosoff have clearly shown that the problem is solved in the purity of the steel, and he has succeeded, as is well known, in producing the very highest qualities of Eastern boulat. On a former occasion I spoke of the observations I had made on the ribbons of dead tint observable on the surfaces of steel guns in the lathe. By means of careful daily records of the forging of the gun ingots, I found that these tints appeared in the boundaries between the hot and the cold portions of the ingot being forged; that is to say, always at those points up to which the ingot was pushed into the furnace. The position and appearance of the strips of dead tint always coincided with the position and form of the limit of heating. If a spot so noted by me was afterwards reheated, then the ribbon of dead tint no longer appeared after turning in the lathe. Besides this, some of these ribbons would disappear as a greater or less thickness of metal was turned off; others penetrated right through the mass of the gun, and never disappeared.

It is further remarkable that although, at times, the transition from the heated to the cold portion of the ingot was so gradual that it was impossible to assign any limit, yet the ribbon of dead tint developed by the turning of the surface of the gun, and corresponding to the above ill-defined limit of heating, was so clearly marked, that it was easy to trace its boundaries with a pencil on the surface of the gun. It must be remarked also that the ribbon has only one well defined margin, that which was turned towards the cold end of the ingot; the other margin is shaded off imperceptibly into the normal tint of the steel. Wishing to investigate the effects of the steam hammer on the structure of steel, I heated a 4½ inch ingot to a bright red color, and subjected it to two heavy blows of a 5-ton hammer, so that one-third the length was not touched at all, the second third was flattened to 3 inches, and the last received two cross blows, under each of which there was a compression of at least 1½ inches. The ingot was then left to cool in the open air, and on being broken it was found that the appearance of the structure of each of the three sections remained identical, not only to the naked eye, but to the most careful microscopical examinations.

I have also drawn attention to the circumstance that, on one occasion, when experimenting on the influence of the temperature to which steel was heated on its hardness in tempering, I ordered a smith to heat a piece of steel to dull red, but he, my mistake, heated it bright red. Wishing to rectify the error, I did not at once plunge the steel into water, but let it first cool down to dull red, and then immersed it. Although the steel was of a quality capable of extreme hardness in tempering, the immersion not only did not make it hard, but actually made it sensibly softer. I have recalled the above circumstances, because in connection with many others, they induced me to investigate the influence of temperature on steel, and formed points of departure from my researches. Space will not allow of my describing my experiments in detail. I must content myself with stating the conclusions to which I have arrived. If steel melted in a crucible is constantly kept in violent agitation while cooling, agitation violent enough to keep all its particles in motion, then the cold ingot produced will have a very finely crystallized structure; if, on the other hand, the melted steel is allowed to cool in perfect quiet, then the resulting casting will consist of large, well-developed crystals. The appearance of these crystals, and generally the tendency to crystallize under these circumstances, will depend on the purity of the steel. As I have already stated, the ultimate purity of the steel consists in that of its two component elements, iron and carbon, and that the best steel is composed of only these two elements. With reference to other elements, the presence of which is supposed to influence the quality of steel, it is impossible to avoid mentioning the opinion of

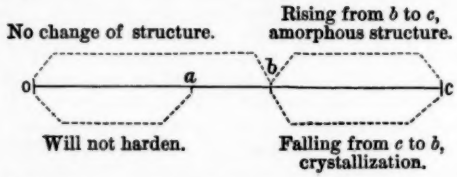
Fremy, who considers nitrogen so essential not only to the formation, but to the very existence of steel, that he has laid down the proposition that "if the nitrogen is taken away from steel it will cease to be steel,"—*Comptes Rendus*, vol. lii, April, 1861; and the supporters of this theory, who go further, and affirm that steel is a union of iron with cyanogen, which can even be seen burning with a violet flame during the process of casting steel. However, up to the present time—1868—the most careful researches of Caron, Marchand, Biot, Bousingault, Rammelsberg, and others, have not confirmed the assertions of Fremy; for, on the one hand, nitrogen is found also in soft wrought iron and in cast iron, and on the other, the quantity of nitrogen found in steel is very variable, and bearing no fixed relation to the quantity of carbon; and furthermore, it exists in such small quantities as to be less than a tenth part of the carbon. For instance, Bussengol found 0.00057 part of nitrogen in cast steel, and 0.00124 part in soft wrought iron.—*Comptes Rendus*, vol. lii, p. 1251. On another occasion, he found in Krupp steel 0.00022 part of nitrogen, and in soft wrought iron and in cast steel. 0.00007 each.—*Comptes Rendus*, vol. liii, p. 9.

With reference to the influence of different metals on the quality of steel, it is necessary to state that some of them communicate a particular color, some diminish the tendency to rust, and others, displacing the carbon, enable the steel to acquire very great hardness in tempering, and so on; but the greater number of substances combined with steel, even in its most insignificant proportions, very considerably lower its quality. For example, the malleability of steel, being in direct relation to the quantity of carbon contained in it, is materially lowered by the presence of foreign substances. Bessemer steel No. 1, containing 2 per cent. of carbon, is hardly malleable—Boman, *Das Bessemern in Schweden*, 1864; whereas, according to Anosoff, pure steel retains its malleability with 3 per cent. of carbon, forming the hardest boulat. Speaking generally, all the efforts of metallurgists to obtain the highest qualities of steel should be directed to separating impurities from the raw materials, so that the produce of their operations should be a combination of iron and carbon; and all the specifics and nostrums forming the subjects of so-called secrets will be found to consist, in effect, not in the introduction of new materials, but in purifying the raw, and only, as a last expedient, driving out pernicious impurities by means of substances less harmful. It may as well be said that tungsten steel has not proved a dangerous rival to carbon steel. The fact is that tungsten, when steel containing it is heated, gradually oxydizes, at first on the surface of the ingots, and then by degrees to the very center, so that after a few heats the steel loses its peculiar qualities. The oxydation takes place even at ordinary temperatures. As I have already stated, steel, cast and allowed to cool quietly, assumes a crystalline structure. If you heat such an ingot to a bright red heat, and allow it to cool without working it in any way, then on breaking the mass you will find that its structure has been altered. In order to explain the law regulating the change of structure produced by heating, I draw a line, on which, as on the scale of a thermometer, I shall mark certain points, corresponding to several determined temperatures.

Let the point *o* be the zero of the thermometric scale: *a* marks the temperature of dark cherry-red; *b* red, but not sparkling; and *c* the melting point of a given sample of steel. The points *a*, *b*, and *c* have no permanent place on the scale, but vary with the quality of the steel (in pure steel this variation depends directly on the quantity of carbon contained); the harder the steel the nearer these points move to *o*, and the softer the steel the farther off, and, speaking generally, with varying rates. The limits of these movements are sufficiently narrow, so that an inexperienced eye would hardly discern them. Not having suitable apparatus for measuring the temperatures, I have been compelled to denote them by the colors exhibited in heating, the various shades of which only an experienced eye can appreciate; and it must be added that the colors named have reference only to hard and medium qualities of steel; for in the very soft kinds, nearly approaching to wrought iron, the points *a* and *b* recede

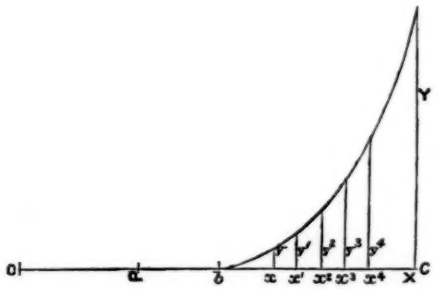
very far, so that, for example, in wrought iron the point *b* corresponds to white heat.

The definition of the point *a* is as follows :—Steel, however hard it may be, will not harden if heated to a temperature lower than *a*, however quickly it is cooled ; on the contrary, it will get sensibly softer and more easily worked with the file. Not having time to enter into the explanation of this phenomenon, I will refer to the investigation of Jullien (*Les affinités capillaires et les phénomènes de la trempe mis en présence*, Paris, 1866) on tempering in general, from which he deduces the very probable conclusions that steel, in cooling from a red heat, appropriates a certain amount of latent heat, the quantity of which is directly dependent on the rate of cooling ; so that the quicker the steel is cooled the greater quantity of latent heat it will contain ; but if the rate of cooling diminishes below a certain limit, then the latent heat all escapes, and no hardening can take place. The actual hardening Jullien explains by the supposition that the carbon assumes an abnormal crystalline condition. I will add from myself that all this takes place only when steel is heated above the point marked *a* on our scale. The definition of the point *b*



is that steel heated to a lower temperature than *b* does not change its structure, whether cooled quickly or slowly. This expression, however, must be taken conditionally, because steel, during long periods of time, and especially under the influence of shocks or vibrations, and at ordinary temperatures, but to a less extent than wrought iron, changes from the finely granular to the course crystalline structure ; and as regards the heated, and therefore softened, condition, and especially at temperatures approximating to that indicated by the point *b*, it is probable that, with the greater facility of motion, the change of structure will take place more rapidly. In my own experiments I have kept pieces of steel at temperatures near to *b* for about eight hours, but after cooling slowly in hot sand I have been unable to detect any change of structure. As soon as the temperature has reached the point *b* the substance of steel quickly passes from the granular (or, speaking generally, crystalline) condition to the amorphous (wax-like structure), which it retains up to its melting point, that is, to the point *c*. In this condition steel possesses the property of imcompressibility, and, at the same time (with respect to the permanence of the amorphism), has an analogy to an exceedingly concentrated solution of a strongly crystalline salt. To make my meaning clearer, imagine a piece of crystalline alum put into a beaker and carefully heated. On attaining a certain determined temperature the piece of alum will appear as if damp, the separate crystals forming the mass will seem, as it were, to be sticking or clinging to each other, forming a mass on the point of melting, and which actually gradually becomes fluid, and forms a solution of the crystals of alum in their own water of crystallization. Now if this fluid mass be allowed to cool, it will again crystallize, and according to the conditions under which this cooling takes place we can obtain any quality of crystals, from the coarsest to grains so fine as to be scarcely perceptible to the naked eye. If the fluid is allowed to cool very slowly, and in perfect quiet, then large regular-shaped, well-developed crystals will be formed ; but if, with the same gradual cooling, the liquid is kept in constant agitation (shaken up), the crystals will come out very small. Allowed to cool quietly but rapidly, the crystals will also be small ; and, finally, the least favorable condition for crystallization is when the liquid cools rapidly, and is at the same time violently agitated. In a word, all depends upon the greater or less *time* and the greater or

less freedom of motion the particles possess among themselves for collection into crystals; the first condition depends upon the rate of cooling, the second, upon the quiet and the greater or less density (thickness) of the mass undergoing crystallization. The same changes take place in the structure of steel heated above the point *b*. The higher steel is heated the softer it becomes, the greater, therefore, is the liberty its particles possess to group themselves into crystals—if the quiet of the mass is not disturbed by extraneous forces; and the slower the temperature is suffered to fall to the point *b* the more time they have for the purpose. At temperatures lower than *b*, as already stated, the structure of the mass does not alter. In this case the action of carbon on iron may be likened to that of water of crystallization on its salt; that is, it may be supposed that carbon at the temperature *b* begins to dissolve iron just like the water of crystallization at certain temperatures commences to dissolve the solid substances of the salt. This hypothesis receives confirmation in the process of cementation, in which the iron must be heated to above a certain temperature or no effect will be produced, no matter how long the bars remain in contact with the carbon; it is very probable that the temperature at which carbon begins to be absorbed in cementation is very near to the point *b*.



The power of steel to become granular may be graphically illustrated thus: On our scale of temperatures *o*, *a*, *b*, *c*, a curved line rises from the point *b*, and the ordinates *y y*, &c., of this curve represent the degree of development of the grains for the corresponding temperatures *x x x*, which become the abscissæ, but necessarily under similar conditions of cooling from the several temperatures *x x* to the temperature *b*. At some temperature X lower than the melting point C, the ordinate Y becomes infinite, and an asymptote to the curve, the practical significance of which is apparent in the well known fact that steel will not endure a high welding heat, but falls to pieces in the fire; and the harder the steel the lower is the temperature at which this takes place, and, therefore, the nearer is the temperature X to *o*, and the farther from C.

In manufacturing articles of steel we try to get them as much as possible of a fine-grained structure, especially if strength or toughness is the first object sought. I say that it is better to obtain steel of a finely crystalline structure, because numerous experiments have demonstrated that the greater the preponderance of the crystalline formation, the larger and more regular the crystals are in a given piece of steel, the less resistance does it offer to fracture, the less tenacity does it possess, and, therefore, men connected practically with the working of steel recognize its qualities by the appearance of its fracture. If the fracture is fine-grained, they say the steel is well forged and consolidated; if it is coarse-grained, it is badly forged and of an open character.

Although we are in the habit of associating with the forging of steel an idea of increased density, yet, in reality, it appears that, in most cases, forging only changes the form of the steel, and, according to the relations between the force of the blows and the thickness of the piece of steel being worked, hinders

crystallization of the mass to a greater or less degree, but does not increase its density—I am speaking only of forging above the temperature *b*, such as is general in working large ingots. The force of the blows is too small to vanquish that gigantic molecular force of heat that keeps the particles of steel at a definite distance one from the other. The problem of forging—at temperatures higher than *b*—consists in this, that while changing the form of the mass of steel it should have no time to cool and crystallize quietly, but should be kept in the amorphous condition till such time as the temperature sinks below the point *b*, after which, if left to cool in quiet, the mass will no longer crystallize, but will possess great tenacity and homogeneity of structure, so that it will oppose in all its parts a uniform resistance to external forces, of course supposing the chemical composition of the mass throughout to be the same. But if the problem of forging was limited to the above conditions, it is easily seen that working steel under the hammer might be dispensed with, and the required form given at once by casting in suitable moulds, and preventing crystallization by rapid cooling. In reality, however, things are very different. The difficulty of forging is aggravated by the circumstance that the cast ingots out of which guns, for example, have to be made are full of pores filled with gas, bubbles penetrating the interior as well as the surface of the mass, and also with scales and cracks due to contraction, so that, as the castings are delivered from the foundry, it would be impossible to make use of them. These bubbles and cracks must be squeezed or pressed together, and this can only be done by powerful mechanical means—by heavy forging. Simply unforged cast steel is neither less dense nor less strong than steel of the same molecular structure, and forged at temperatures higher than *b*.

To convince myself of this, I made a number of experiments, first on the density of the two kinds of steel, and found that in most cases forging had diminished the specific gravity; and, secondly, I found that the tenacity of the cast steel was in nowise less than that of the forged, provided, as I said before, both have the same structure. To prove this, I took a cast ingot of coarse crystalline structure. I had it cut longitudinally into four parts. One of these parts was turned down in the lathe, and tested in the proving machine. The second piece was heated to bright red, and vigorously forged under a three-ton hammer, the forging being stopped when the temperature fell to very nearly the point *b*; the specimen was then turned down, and also tested in the proving machine. The third piece was made red-hot, very nearly the same temperature at which the forging of the second piece terminated, and was allowed to cool in the open air without being forged. Having broken a small piece off this last specimen, I found that it had assumed a finely granular structure very similar to that of the second forged specimen. The third sample was also turned down in the lathe, and tested. The three specimens are now before you, and you may judge for yourselves what varieties of structure the self-same piece of steel may be made to assume. The results of the experiments are given in the following table:

	Ultimate strength, in tons, per sq. inch.	Ultimate extension.	Diameter of specimen —inch.	Dynamic resistance per cubic inch in inch tons Ultimate strength $\times \frac{1}{2}$ elongation.
1st. Unforged specimen	34.8	0.023	0.885	0.8
2d. Vigorously forged specimen	41.5	0.053	0.85	1.1
3d. Not forged, but made finely granular by heating.....	38.7	0.166	0.63	3.21

I must also remark that on the fractured surface of the third sample, as you may observe for yourselves, there is a spot of iron occupying about one-sixth

of the area, and which was undoubtedly the cause of premature fracture, for the appearance of the fracture clearly shows that it began at that spot. In order to establish the propositions I have advanced, it will, of course, be necessary to institute a complete series of experiments.* As regards trials by bending and breaking under the hammer, an immense number of experiments have convinced me of the correctness of my views.

From what has been said above, you must have perceived that the whole point lies in the structure of the steel, and that for successful forging the heated ingot, after it is taken out of the furnace, must be forged as quickly as possible, so as to leave no spot untouched by the hammer, no spot in which the steel might crystallize quietly, because, as I have said, the heated piece of steel must be considered in an analogous condition to a saturated solution of a strongly crystallizing salt, which, the moment it is allowed to cool quietly, develops large crystals. I repeat that this has reference to temperatures higher than *b*.

To show you how great is the tendency to crystallization in steel heated up to a high temperature, and allowed to cool quietly, even for a short time, I have brought some specimens by which you can judge of this tendency. The larger specimen was obtained under the following circumstances: An ingot of soft steel prepared for forging was allowed to remain in the furnace for half an hour after it had been heated to a bright orange heat, because the hammer was occupied by another forging. But, in order not to overheat the ingot, the smith reduced the temperature of the furnace, and gradually let down that of the work to a bright red. If you will now call to mind what I have said about the tendency of steel to crystallize in cooling between the temperatures *c* and *b*, you will readily believe that during this half hour the ingot had time to change its internal structure from the amorphous to the crystalline, a change which was greatly assisted by the extreme softening it had undergone at the higher temperature, which presented favorable conditions for the movement of the particles within the mass. As soon as the hammer was at liberty, the ingot was taken out of the furnace, and placed on the anvil; with the very first blow on its middle, the end of the ingot tumbled off from the effects of the concussion; the form of the fracture you can see on the first specimen before you. The remaining samples are taken from other ingots under similar circumstances, and they all show how strongly the crystals have developed themselves; and, moreover, each crystal seems to have formed itself in an independent manner, with so little cohesion to the neighboring crystals that one shock was sufficient to separate them, and allow the overhanging piece to detach itself by its own weight. The specimens show that fracture has taken place only along the surfaces of the crystals, and nowhere through the body of them.

It might be concluded from the incident above described that the ingot was completely spoiled, and could not be forged again. But such a conclusion would be quite erroneous. It is true that the higher the temperature of the steel, the more susceptible is it to the action of the furnace gases, and the quicker it changes its chemical condition, so that if kept to a high temperature in the furnace it will gradually lose its carbon and be slowly converted into iron, burning. The example I have cited, however, is only a case of overheating; and in order to know how to correct the mistake made we must turn to the conditions of crystallization. Let us, again, take the beaker of melted alum. Suppose the melting point to be t_0, and that the solution was further heated up to t_1 under which operation it would continue liquid. Let the temperature fall gradually, keeping the solution perfectly quiet, then we shall find that at some temperature t between t and t_1 the salt will begin to crystallize; but it is only necessary to shake up the solution to make the crystals dissolve again at the same temperature t. We shall notice, also, that there is scarcely any cohesion between the separate crystals so formed, and if we do not wish to disturb their mutual relations, we shall have to allow the crystallizing solution to cool below the temperature t_0, and then by a second heating up to t_0 we

* 1875. Since the above was written, numerous experiments at the Abouchoff Works have fully demonstrated the truth of my views.

should again receive a fluid mass. The same result would be obtained by a simple single increase of temperature ; the difference lies in this, that the liquid produced from the destruction of the incipient crystals in the three cases stated has three distinct temperatures. Applying this reasoning to steel, it is easy to see that, in the case cited, the temperature of the ingot should have been raised again before forging, so as to impart to it an amorphous structure ; it should then have been quickly and unceasingly forged all over its extent while the temperature was lowering somewhat, and the tendency to crystallization decreasing. Or the particles that had commenced to crystallize might have been brought into a motion corresponding to the shaking of the beaker, but very carefully, so that the crystals formed should not fall to pieces, in other words, hammered with the very lightest blows ; and the temperature being higher than *b*, the crystals would have run into each other, the ingot would have assumed the amorphous condition, after which it might have been worked like a piece of wax. It is, of course, better under such circumstances to allow the over heated ingot to cool quietly, then to heat it again, taking care not to allow the temperature to rise too high and give the mass an opportunity of again changing the restored amorphous condition to a crystallized one ; the forging will then not require any special precautions, and the ingot will not tumble to pieces.

It is worthy of remark that if a piece of steel be so greatly overheated as to assume a strongly crystalline structure, and become liable to destruction at the least shock, and is allowed to cool quietly, then the separate crystals, if they have not been separated by external forces while in a heated state, become so joined or grown together that the fracture of the cold piece takes place, not along the surfaces of the separate crystals, but indifferently through their mass, though the junctions of the fractures of individual crystals generally take place along their planes of adhesion, owing to which such fracture is always very sparkling. From this it is evident that the close contact of two surfaces of metals of the same nature heated to a higher temperatnre than *b* is sufficient to produce union. This is, in fact, welding ; and if, in welding, hammering is always necessary, it is only because, in the first place, it is very difficult, without hammering, to press two pieces one against the other ; and, secondly, that it is otherwise difficult to free the surfaces to be welded from the slag which alone protects them from oxydation during the heat. Of course the more homogeneous or analogous the structure of the two pieces the more perfect will be the union ; but one of the first conditions is that there should be the fullest contact between the unoxydized metallic surfaces.

Up to the present we have been discussing the forging of steel only at temperatures higher than the point *b*, and we have stated that the aim of the forge master must be to change the form of his ingot in such manner as to keep all its particles in constant motion, and so hinder the formation of crystals, which materially lower the tenacity of the steel. Let us now see what circumstances arise in forging below the temperature *b*. The fracture of a piece of cast steel presents a rough surface consisting of groups, as it were, of crystalline *débris*—so-called grains—piled one on another, and generally of a very irregular form. Under the microscope it is easy to see considerable interstices between the groups of grains, and, on more minute examination, spaces may be observed between the grains themselves, which form with each other various interlacings and combinations. In a word, steel, under the microscope, has a more or less porous structure, at first sight, destructive of any belief in the tenacity ascribed to it. Time will not permit me to enter into details relating to the appearance, size, and arrangement of the grains ; it answers my purpose simply to direct attention to the fact that among the grains of steel there are numerous vacant spaces—pores. The question arises—what becomes of these pores when the steel, being heated up to the temperature *b*, acquires the amorphous condition ? In all probability, during the rise of temperature from *o* to *b*, the expansion of each individual grain, formerly in itself a compact body, goes on incomparably faster than the increase of the external dimensions of the piece of steel, so that the period at which it

assumes the amorphous condition coincides with the moment when the atoms composing the individual grains, moving away from each other under the influence of heat, fill up these spaces; it is, therefore, conceivable why steel becomes at this stage incompressible—why it is impossible to increase its density by hammering, no matter how heavy the blow may be.

It is evident, from the above reasoning, that if we wish to increase the density of steel, to approach its component grains to each other and so bring them to a more energetic cohesion, we must do so when not opposed by the force of heat, that is only at temperatures below the point *b*. Thus, forging at temperatures below the amorphous condition has the important advantages we are in the habit of ascribing to it. We never forge large ingots below the temperature of amorphous structure, and guns never were and never are forged below that point, because for gun steel it lies, as I have already stated, at a dull red heat, that is, within limits below which, with the mechanical means at our disposal, we can produce no effect on large steel masses. It would be necessary to forge small ingots under our largest hammers, and what an exhibition of inadequate mechanical appliances would be presented if a 4-pounder gun were forged under a 35-ton hammer! The practice now is to forge the 4-pounders under the 3-ton, and sometimes the 5-ton hammer, while the 35-ton hammer is used for the 6 in., 8 in., and 9 in. guns, in which the diameter of the cast ingot reaches up to 40 in.; but if you picture to yourself such a large mass of steel heated to a non-sparkling red heat, you will perceive that the utmost efforts of the heaviest hammer will remain inoperative—it would be impossible to forge it. Forging is carried on at points below the amorphous condition, but it is only in very small pieces, and by those who have some knowledge of the influence of heat on steel.

If a cast ingot of any given structure is heated not higher than the point *b*, then in its heated state it will retain its structure. If it was crystalline, then in a heated state it would be composed of the same crystals, which, however, would be considerably softened. If the piece of steel be forged in this condition, then its crystals or grains, being driven against each other, will change their shapes, becoming elongated in one direction and contracted in another, and the increase of density becomes so considerable that I have found the specific gravity rise as high as eight, which I have never yet found in steel forged at temperatures higher than *b*. This comparatively cold forging communicates to the metal great clearness of ring, it is no longer so easily worked with the file, weak sulphuric acid produces hardly any effect on it, and so on. With regard to its absolute tensile strength, I regret very much that I have been unable to make any experiments; but there can be no doubt that it is very high. The fracture of such steel has a silky lustre, and under the microscope it is very difficult to trace the limits of the individual grains; they present the appearance of waxy little balls squeezed together under a powerful press. If you cut off and polish the surface of a piece of steel so treated, and then immerse it in weak sulphuric acid, after a time a pattern will form on the surface, which presents the appearance of an irregular interlacing of crooked lines, the size of the network depending on the original size of the crystals, the manner of forging and so on. I have already stated that the tendency to crystallization, as well as the form of the crystals and their relative positions, depends on the purity of the steel, and the conditions under which the cast ingots are poured and cooled. In the higher qualities of boulat, the tracery developed by acid is of remarkable beauty and regularity.

The cause of the patterns appearing is the various groupings of the crystals during their formation. These crystals have not the same chemical composition; the lighter parts of the tracery contain much more carbon than the darker parts—a fact which I have demonstrated—and consequently, simultaneously with the grouping of the crystals or grains, there is a segregation of like chemical compounds. If you heat the piece of steel thus marked—damascened—up to the temperature *b*, or a little higher, and allow it to cool again, you will no longer be able to obtain any pattern by the action of acids. From what has been

already said, the cause of this must be quite plain, and I need not dwell on it any longer. In conclusion, I will show in what manner the properties of a cast steel ingot may be best taken advantage of. With respect to forging at temperatures below the amorphous condition, we can only, as I have already stated, make the smallest guns under the largest hammers. We have at present no mechanism capable of dealing with large masses at low temperatures; but if it were possible, there can be no doubt that guns so forged would be of the very best quality, and their reception into the service would be facilitated by the appearance of the patterns brought out by weak acids, because of the close connection which exists between the quality and the appearance of the steel so treated.

To adapt ourselves to the means possessed by our steelworks, we must strive to obtain our material as much as possible of a fine grained structure; and with this view it is necessary, as we have already seen, to heat the ingots to a high temperature, and to keep forging them until they cool down below the temperature *b*, because, by so doing, we shall be giving the work the required form, and at the same time prevent its structure becoming crystalline, but rather make it approach the amorphous condition. But if we examine the circumstances attending the practical application of this rule to the forging of ingots intended for heavy guns, we shall find that, in many cases, it will be impossible to carry it out, and a forging will be obtained the structure of which is far from uniform, and more likely to be coarse crystalline than fine-grained. We shall attain our object more easily, and with more certainty, if after having given the forging the desired shape, we alter its structure to the homogeneous amorphous condition by heating it, and then fix that condition by rapid cooling to a temperature lower than *b*. For this purpose, it is of course necessary to surround the ingot after heating by some rapidly cooling medium.

From what has been said above, it is evident that, with the same rate of cooling, we shall fix the amorphous condition of the steel with the greatest certainty when we exceed the temperature *b* as little as possible; and for that reason it is well to determine that temperature for each ingot beforehand. Having, therefore, heated the finished forging, or better still, the rough turned and bored gun, to a temperature somewhat higher than *b*—a point which ought to be determined by the pyrometer—let it then be plunged as quickly as possible into the cooling medium, be it water, oil, or what not, and having reduced the temperature of the work to below the point *b*, allow it to finish cooling gradually, so as to prevent, as far as possible, internal strains due to sudden and unequal contraction. To show you what changes may be produced in the structure of steel by the operations described, I lay before you three specimens. They are all broken from the same piece of steel. The first specimen exhibits the coarsely crystalline, porous structure that characterized the ingot, notwithstanding that it was well worked under the 35-ton hammer. The second sample was heated to a little above a bright red non-sparkling heat, and then allowed to cool in the open air. Comparing the fractures of these two pieces, you perceive the structure is totally different, though offering one surface to the other proves by the fit that the two pieces were at one time united, and that neither piece has been touched by the hammer since they were broken asunder. The third fragment of the same piece was heated to a bright red heat, and then quickly plunged into water, and left till the temperature sank to a reddish-brown heat; it was then taken out and allowed to cool in the open air. The fracture shows that on the external surfaces, for a depth of 0.1 in. the amorphous condition has been completely preserved. In the centre of the piece the mean diameter of the grains, as measured by the microscope, is 0.0004 in., while the mean diameter in the first piece was 0.15 in., and in the second, 0.005 in. To this I may add that to break the first piece one blow of a hand-hammer—? sledge—was sufficient, to break the second required five such blows, and the third piece had to be broken under a steam-hammer, because the strength of the smith was inadequate for the work.

A similar experiment was made with the tire of a railway wagon wheel. A

piece of an ordinary tire was broken by a 5-ton hammer into three pieces. One of them was heated to a light red, and then thrown on the floor to cool in the open air to the ordinary temperature. It was then put under the 5-ton hammer, and required four heavy blows to break it, whereas the first piece broke under one blow of the same hammer. The third piece I heated to a bright red heat, plunged it quickly into water, and took it out again when cooled to a reddish-brown heat, and then found that it required five heavy blows of the 5-ton hammer to break it. Therefore, I say, that in order to fix the amorphous condition, and thereby to increase the tenacity of steel, it is necessary to plunge it, after heating, into water. It may be cooled in oil, but, in the first place, this is expensive, and, in the next, numerous precautions have to be taken to prevent the oil catching fire. With respect to cooling in water, I must add that the conductivity of hot metal is very small, and that although the external visible parts soon show the desired fall of temperature, yet the central portions remain very much hotter; it, therefore, requires care, experience, and many precautions to avoid the too rapid cooling of the outer layers, and the consequent development of severe internal strains. Time will not permit me to treat this subject in greater detail. I can only state my opinion that not only should every gun be subjected to the treatment above described, but also every article made of steel, as, for example, tires, axles, shafts, &c.*

It follows, from the principles laid down, that any steel article having, from constant work and concussion, lost its original strength, that is, assumed a crystalline structure, as happens to wagon axles, engine shafts, &c., can, by the help of the process above described, be completely restored by having communicated to it, if not an amorphous structure, at least one so finely grained as to be nearly equal to it, and, at the same time, a compactness and tenacity it very likely did not possess when newly taken into service. I trust that you will now fine it easy to understand the circumstances and facts which I brought under your notice at the commencement of this paper. I have heard with pleasure, from a friend just returned from England, that at the Woolwich Arsenal they have adopted the practice of heating their steel gun linings, after forging and rough turning, and plunging them into oil; he was unable to give me any details of the operation, as he only noticed it in passing, but the object of the treatment was, he ascertained, to give the the steel greater tenacity. It is possible that I may soon obtain information as to the reasoning which led to the adoption of this practice, and I shall be exceedingly pleased if I find it is based on theories similar to those I have had the honor of laying before you this day. With respect to the doctrines I have been advocating, I have been accused of being too bold in my conclusions, but I am prepared to take a still more decisive step, and to announce the opinion, resulting from my observations, that "future investigation into the question of forging steel will not deviate from the path into which we have this day directed it."

* 1875. A wagon axle treated in the above manner, and cooled in water, withstood twenty-two blows of ¼ ton weight falling fourteen ft., and remained unbroken.

In a report drawn up by the deputation of workmen who were sent from Paris to the Vienna Exhibition three years ago, and only lately published, the following arguments are advanced in favor of piecework:—"In most of the Paris manufactories and workshops workmen are paid by the hour. Now, it always happens that the employer fears that the amount and quality of the work executed is not worth the price he pays for it; the workman, on the other hand, being underpaid, is always afraid of doing too much. In self-defence, the employer resorts to vexatious precautions which are of no use to him, and which only excite the resentment of the workman—a resentment which he loses no opportunity of displaying. This latent animosity between the employer and the workman is to be deplored in the interest of both parties, and the best way of putting an end to it is to adopt the principle of piecework, by which the independence of the workman is effectually secured."

—*The Engineer.*

THE ECONOMY OF FUEL—EXPERIMENTS ON A BOILER AND A STEAM ENGINE 110-HORSE POWER, MADE AT MAESTRICHT.

By L. LHOEST.

From the "Universal Review of Mining."

II.

Effective Results.—As has been said, the engine experimented upon is one where cutting off the steam was varied by the governor. With reference to the work done by the engine, this altered a good deal from one time to another, whilst the diagrams demonstrate such large and continual differences that it is difficult to determine with precision the average ratio of steam admission. It will not, however, be very far from the truth if it be assumed that this average has been about one-thirteenth, or for about 1-3.9 of the stroke of the smaller piston. The examination of the diagrams goes to prove that superheated steam, contrary to what has been generally believed, appreciably expands according to Mariotte's law, in the smaller cylinder; and beyond this there is the singular fact that the lowering of the pressure is less even than the formula demands. Although this can be explained, so far as regards saturated steam, by the re-evaporation of the water carried into the cylinder with the steam, this explanation does not in any way apply to superheated steam, and the phenomena is still more curious from the fact that it is evident Mariotte's law is not applicable when the steam expands, and at the same time accomplishes work. This work cannot, of course, be gratuitous, as it were, for the theory of mechanical equivalent of heat requires that there should be a corresponding fall in temperature. Yet here is an actual fact frequently observed and recorded; its explanation, however, lies in the objectionable waste of steam in clearance. In the machine experimented upon, besides the entrance and discharge passages, there remains at the end of each stroke a space of nearly a centimeter (.394 in.) between the piston and the ends of the cylinder. If account be taken of these spaces in the diagrams, Mariotte's law will be found very nearly applicable. We will proceed at once to the consideration of the points arising from the actual measurements which have been made:—(1.) The pressure of steam at admission has differed 0.2 atmosphere between the interior of the boiler and its entry into the cylinder. (2.) The back pressure in the smaller cylinder during its communication with the larger one has differed from the pressure in this latter by only 0.076 atmosphere on the average. This difference, which varies from 0.13 atmosphere to 0.05 atmosphere according to the position of the pistons, must be looked upon as extremely small. (3.) The vacuum in the larger cylinder differed from the barometrical vacuum by 0.15 atmosphere, whilst that in the condenser differed only 0.10 atmosphere.

During part of the first trial the vacuum left a good deal to be desired, in consequence, probably, of the leakage of air and the employment of too small a quantity of water in the condenser. These facts have had a serious influence on the working of the engine, which otherwise would certainly have been more effective; and the proof of this is found in the extra nine per cent. of heat units per horse power per hour escaping from the condenser during the first twelve hours of the trials, when the vacuum was unsatisfactory.

As has been said, the average work of the engine has been estimated by totaling the diagrams taken during the experiments, and subtracting from the figures thus obtained the fractional resistance. The valuation of this last is, however, open to criticism. By how much is it necessary to increase the allowance for friction of an engine as determined, when running unloaded, in order to obtain its friction when loaded? A brake alone can determine this question; but in the absence of one, we have taken as

correct the results otherwise obtained, from which it appears contrary to what has always been the belief,—that the frictional resistance is far from increasing in proportion to the work done by the engine. Experiments with a brake on a beam engine of 120-horse power have been made by M. Burnat, the proportions being 9.18-horse power of friction when running free, to 11.07-horse power when loaded; and with reference to another beam engine of the same power this gentleman found the friction loss to be 1.09-horse power when free, to 12.02-horse power when loaded.

M. Groseteste has made experiments with a beam engine of 213-horse power and found that the friction *in vacuo* was equal to a power of 19.78 horses, and that, while exposed to the atmospheric pressure, it was equal to a power of 20.74 horses; that is to say, that there was a difference of about half a horse power in the case of an engine equally powerful with that under notice. We ourselves have, within narrower limits, conducted a series of experiments with a brake dynamometer on a beam engine of 20-horse power, and we are unable to state the difference in the amount of friction when it was exposed to the air *in vacuo*. It will be understood we do not assert that the resistance is equal in both cases, but only that the difference is so slight as to be sometimes inappreciable when experimenting with the brake dynamometer.

From the whole of these statements, it is believed that the friction of the engine under notice when loaded differed by about one-horse power from the friction when it was not loaded.

Steam Jackets.—As has been stated the smaller cylinder is not provided with a steam jacket, except at the point of communication between it and the larger cylinder; on the other hand, the larger cylinder had three parts of its surface surrounded by a steam jacket, which, however, could be shut off, if wished.

During the first and third experiments, steam was admitted into this jacket at the same time as into the smaller cylinder. During the second and fourth trials the steam in this jacket was replaced by air. Nor was any sensible change in the duty of the steam produced by this alteration, save, perhaps, that with equal quantities of steam admitted, the effective power of the engine was slightly diminished. Thus in the first and third experiments, the effective result in the larger cylinder was, on the average, 40 per cent. of the whole work done, whilst in the second and fourth trials it amonted only to 36 per cent. This difference, for the same amount of work, readily explains itself by the fact of there being a larger admission of steam into the smaller cylinder. As to the consumption of steam per horse-power per hour, it was scarcely at all augmented by doing away with the steam jacket, since the increase of 0.224 kilo. of superheated, and of 0.04 kilo. of saturated steam both fall within the limits of possible errors of observation. This difference would be somewhat greater if the water condensed in the steam jacket were again utilized. These results, then, although in some measure merely negative ones, do not confirm the conclusion so strongly attested by Messrs. Hirn, Combes, and many others, in favor of steam jackets; and although, indeed, it may in some measure be overstepping the bounds of these experiments, this appears to be the place to offer a few critical observations on the manner in which these steam jackets have been looked upon by different authors, who have variously regarded them either as of immense economy, as having no effect, or as being positively injurious. It appears, then, that these contradictory conclusions indicate that the questions are too frequently only examined from a general point of view; on the other hand, is it of any use to enunciate general theories with reference to an accessory part of an engine, the effect of which varies so much, according to the construction of the machine and its method of working? All that it seems right to say of steam jackets is, that they slightly increase the power of the engine, and tend towards economy, for all steam condensed in the jacket is steam which has yielded in its work all positive and latent heat, and, consequently, it is steam more usefully employed than that which escapes from the cylinder whilst still containing its latent heat. M. Bède, in a treatise of great lucidity on this question arrives at conclusions highly favorable to steam jackets. As we take it, however, these conclusions are scarcely in accordance

with the reality, for the author assumes, in a general manner, that the steam jacket can supply to the interior of the cylinder the heat necessary to maintain the steam in good condition during the stroke, whereas, in most cases, the sides could not transmit even one-half of the heat necessary for this; and besides, as M. Combes has demonstrated, this effect might be injurious,

M. Dwelshauvers applies Rankine's formula, $pv^{1\frac{1}{16}}$=const., and by its aid arrives at the conclusion that if the steam jacket does produce economy, that economy does not exceed one per cent., which would certainly not be a fair compensation for the difference in price. But, whilst every respect is due to such an authority as Rankine, as also to the really scientific method followed by M. Dwelshauvers in his theory of steam movers, may it not be repeated here first of all that such a formula can only be varied for a machine of fixed proportions; and, further, that it is necessarily insufficient. It has been verified by the help of a pressure indicator attached to condensing engines not using superheated steam. But even of these engines are there not endless varieties? Has the engine one or two cylinders on Woolf's system? Is it worked with a slow or quick stroke? that is to say, is there, on the average, much difference in temperature between the two surfaces of the cylinder? but, besides the thickness of the metal, what is the diameter of the cylinder, and how far is it thence possible to carry the heat of the steam jacket towards its center? These conditions, and many others which are omitted, modify entirely the action of a steam jacket, and until their effect is definitely determined, it is impossible to enunciate formulae for estimating its utility.

Besides all this, it is known that the indication of the steam pressure alone is not sufficient to enable a perfect analysis to be made of the effect on the work done, produced by a steam jacket. It is necessary to examine still further the internal working of the steam—to analyse the condensation during its stay in the cylinder and during the discharge; and, above all, to determine not only the volume of the steam introduced, but also the weight thereof, this weight being always greater at equal pressure and volume without a steam jacket than with one. If so much time and space are given to the consideration of this point, it is because it is one of the most important and most difficult questions of applied mechanics, which it would be most desirable to see solved experimentally rather than by the aid of speculative formulae, which so frequently mislead from generalizing what demands particular application. The question, in fact, is, in certain cases, that of an economy amounting to from fifteen to twenty per cent., with a more than proportionate increase of power. This increase of power of twenty per cent. would, apart from any fuel economy, amply compensate for the increase of ten per cent. in the price, at which figure M. Dwelshauvers puts the extra cost of a steam jacket*.

Effect of the Superheating.—These experiments prove then, on the average, that the use of superheated steam effects an economy of ten per cent. in the coal, and of 12.7 per cent. of the steam, and it appears evident that these savings could have been considerably increased had it not been for the considerable loss of heat between the boiler and the engine.

Heat given off by the Engine.—The best confirmation of the economy of superheating on the one side and of the excellent work done by this engine, even without the application of superheating, is found in the estimation of the heat units given off by the machine to the condenser. This method of determining the duty of engines by their discharge is probably one of the very best, and far preferable to that of estimating them by the quantity of fuel burned per horse-power per hour. Another plan of estimating the effective duty of an engine is to measure the quantity of steam consumed per horse power per hour. It may, possibly, be more exact when nothing but either superheated or perfectly dried steam is used, but this method is subjected to inevitable doubt, arising from the fact that saturated steam always carries with it a certain

* It appears that at Bleyberg, where a powerful steam pump has been erected, on Woolf's system, the steam jacket has been temporarily done away with, and a marked increase in the consumption of fuel has resulted. We regret that we are not able to obtain accurate official information on this subject.

quantity of water in a vesicular form. The method of determining the work of an engine by the heat given off, which is naturally as much less as the quantity of steam or heat supplied to the engine diminishes beyond the reach of the objections which have just been expressed with regard to the other two systems. More recently Messrs. Donkin and Farey have attempted, by a very ingenious outfall apparatus, to measure continuously the quantity and the temperature of the condenser. It has been preferred, as has been seen, however, to obtain a measurement by fixed and determinate quantities which measurement can, of course, be repeated as often as may be desired, and, although more troublesome, its exactness may unquestionably be guaranteed.

The delivery of the air-pump has, on the average, been as follows:—During the first trial, 350.470 kilos. per minute at a temperature of 30.12° average 364.06 at 29.44°. During the second trial, 378.542 kilos. at a temperature of 27.26°, average 364.06 at 29.44°. During the third trial, 406.080 kilos. at a temperature of 29.90°, average 405.54 at 29.70°. During the fourth trial, 405 kilos. at a temperature of 29.50°, average 405.54 at 29.70°. As the temperature of the condensing water was invariably 9.75° C. the discharge with superheated steam added per minute to this injection water $346.06 \times 19.69 = 7168.34$ for 120.326 horse power; and with saturated steam, $405.54 \times 19.95 = 8090$ heat units for 121,540 horse power. Thus, in the first case, 59.57 heat units per horse power per minute; in the second case, 66.55 heat units per horse power per minute were discharged. If, besides this, we take account of the condensed water in the steam jackets, we find that with superheated steam they have received on the average per hour 53.10 kilos. at the temperature of 95°. This temperature was at the engine 153°, as the steam was there condensed under a pressure of 4.2 atmospheres; but it was only measured when cold and merely under atmospheric pressure. The heat units given off under this trial were thence $53.10 \times 153 = 8124.3$ per hour, 135.4 per minute—1.12 per horse power per minute for superheated steam; whilst these have been found raised for saturated steam to the following:—$79.12 \times 152.7 = 12{,}082$ per hour, or 201.2 per minute, say, 1.55 per horse power and per minute. Thus, with superheated steam, there were given off 60.69 heat units per minute per horse power; ditto, ditto, of saturated steam, 68.20, leaving a difference of 7.54, or 11.2 per cent. It is worthy of remark how closely this difference approximates to that given above for consumption of fuel and steam, and hence may be deduced reasons for a certain amount of confidence in the correctness of the observations made.

Duty done by the Engine.—As was done with reference to the boilers, it is now proposed to present a balance sheet of the engine; that is to say, to endeavor to account for the heat units which were supplied to it. For this investigation the results of the first trial are selected because it was the longest, and the one the results of which have been best determined. During this trial, the engine received, per hour, 883.6 kilos. of steam at an effective pressure of 4.20 atmospheres, and at an average temperature, as taken at the cylinder, of 193°. According to the researches of M. Regnault, the heat of 1 kilo. of this steam prior to superheating would be

$$606.5 + 0.305 \times 153.6 - Ap\,(V_1 - V_0) = 653.3 - Ap\,(V_1 V_0).$$

A representing the heat equivalent of work done, p the pressure of the steam, V_1 and V_0 the respective volumes of 1 kilo. of water and 1 kilo. of saturated steam. Superheating adds to this internal heat a further quantity, the exact valuation of which in the present state of our knowledge is somewhat doubtful. Adopting, however, here provisionally, as we have unhesitatingly done, for the boilers the figures 0.4805 as representing the specific heat of the steam under fixed pressure, the internal temperature of the saturated steam would be increased by superheating by $0.4805 \times 39.4 - Ap\,(V_1 - V_0) = 18.9 - Ap\,(V_2 - V_0)$, heat units; V_2 representing the new volume of steam from the influence of superheating. Adding together the two parts composing the total heat of the steam, there is found

$$572.2 - Ap\,(V_2 - V_0).$$

It scarcely seems necessary to make

an estimate of the heat lost by the expansion of the steam, because the coefficient of expansion, $\frac{1}{110}$, of steam under constant fixed pressure has scarcely, as yet, been definitely determined. The question here is of a condensing engine where the steam after having acted on the piston, is discharged into the condenser at exactly its original volume represented by the feed water, and thus gives back the heat originally absorbed by its expansion.

Neglecting, then, this heat, which has, as it were, for a while, disappeared and then been returned, we may debit to the machine per hour $883.6 \times 672.2 = 593{,}956$ heat units, for which it has to render an account of the corresponding duty done. This duty may be divided as follows:

1. Heat transformed into mechanical effective work.
2. Heat contained in the water of condensation in the jacket and in the pipes.
3. Heat given off with the water of the condenser or the air pump.
4. Heat lost by radiation, or carried off by contact with the different parts of the engine.

(*See Table on following column.*)

	Heat units.		Per cent
(1.) The work done by the machine, including therein the friction, was during the first trial equal to 120.172 horses, representing, per hour, 324.880 kilos. Admitting the figures 424 as the mechanical equivalent of the heat, the effective duty has absorbed	76,524	or	12.88
(2.) There has been collected, per hour, in the steam jacket, 67.32 kilos. of water at a temperature of 153.6, as has been explained above. There is hence a loss under this head of.....	10,340	or	1.74
(3.) After making deductions for the heat units carried into the condenser by the water, of which the temperature was 9.75 deg., there escaped from the air pump per minute 7489.44 heat units, or per hour.....	449,366	or	75.65
(4.) The heat lost by radiation and carried off by contact with different parts of the machine can only be estimated differentially. This difference being understood to absorb, at the same time, all the errors which may have crept into the observations and calculations—say, then.....	57,726	or	9.72
Total...	593,956	or	99.99

In this table there is, however, a correction to be made, The feed of the boiler having required 883.6 kilos. of water per hour, there was re-used, or might have been again utilised, 67.32 kilos. 153° C, —say 10,340 heat units; 816.28 kilos. 31.12° C.—say 25,402 heat units. Total, 35,742 heat units, or 6.01 per cent. of the steam.

Having, then, regard to this correction, the duty of the engine would be 18.89 per cent., from which, however, it is necessary to subtract 3 per cent., the approximate loss sustained by the steam in its transit from the boiler to the cylinder; the effective work is thus reduced to 15.59 per cent., which, combined with that determined for the boiler, say 59.59, gives as the definite duty of the machine which has been examined, 9.46 per cent.

This result is certainly not flattering to our mechanical science; but, nevertheless, the engine under notice appears certainly to be an advance—so far, at least, as present knowledge goes—on any of which the results have hitherto been published. There was hence good reason indeed to say at the commencement of this treatise that much yet remained to be done, The first condition of all progress is to be able to render an account of what has already been done; and it may be repeated here, that to this end it is absolutely necessary to proceed by experiment, and thus determine the total amount of losses. This is what has been attempted in this short treatise. Unfortunately, however, it leaves much to be desired; first, because it can only be looked upon as decisive with reference to a single engine; and, secondly, more than one detail has not been satisfactorily observed nor sufficiently investigated—time did not permit it—but it is to be hoped that the questions at issue may be taken up by others and carried further towards distinctly definite results.

THE ECONOMY OF FUEL—NOTES ON THE EXPERIMENTS OF M. LHOEST, BY V. DWELSHAUVERS-DERY.

After reading the treatise by M. Lhoest, which immediately precedes this paper, we are quite in a position to appreciate the patience, the knowledge, and the deep insight of the author. It is, I believe, the first time that trials of this kind have been made here, and M. Lhoest has known how to turn to account all the experience gained by others, so so as to be able to speak with a considerable amount of precision. It is one stone more added to the building, and theory will not be tardy in arranging the materials which are contributed to her by individual experimenters. Then we shall possess results which will be fit means to serve as guides to the managers of engine works, and not merely those which are applicable only to this or that machine. Such is, in fine, the highest aim of theory and practice; and we owe much to M. Lhoest for having brought us nearer to it.

Let us be permitted, however, to make a few observations on the above named treatise. We have seen with regret, at the commencement of a paper with so high a scope, written by an experimenter so skilful, a reproduction of the error already too widely spread, that "our best steam engines utilize scarcely the eleventh part of the power contained in the coal, the raising of which costs so much. M. Zeuner has done justice to this error, and it is of importance to prevent its gaining further ground. If our engines give out so little—if they are so inferior to the worst form of water-wheel, it is that their principle is bad, and they must be altered throughout. Such is the logical deduction from the error quoted—an error which has driven so many inventors to lose their time in designing engines to replace those worked by steam, such as hot-air engines, engines to be driven by air and steam mixed, by carbonic acid gas, &c. Now the fact is, on the contrary, that the work actually given out by our engines, is very high in proportion to its theoretical amount; but they have been treated with injustice in a manner which I shall now endeavor to explain.

I will suppose a system composed of two bodies only—the earth and a ball which I hold in my hands. The tendency of the latter is to fall; and if I did not retard it, and if other bodies did not retard it after me, it would fall to the center of the earth, and would even pass that point. This ball then possesses the power of traversing the whole of the space contained between the point where I hold it and the center of the earth; but if I oppose to it a resistance infinitely smaller than its own weight, it will conquer this resistance and move towards the center of the earth, performing a work equal to its weight, Q^k multiplied by $R = 6{,}360{,}000$ meters nearly. It may be said then that this ball contained within itself a latent power of Q R kilogrammeters, which it has been obliged to exert in removing it from the center of the earth and placing it in its present position. We may profit by this property in the removal of the work of a body from one place where it cannot, to another where it can, be used. If this ball be left to itself, its speed will increase until it reaches the center of the earth; it will pass this center, its speed gradually diminishing; it will proceed as far as the other extremity of the diameter; then it will return and execute the same oscillatory movement for our benefit. But if, after it has acquired a small speed, v, we oppose to it an available resistance equal to its weight whilst it falls from a height of 10 meters, its speed remains constantly equal to v, and the available work which we have stored up is $Q \times 10$ kilogrammeters. That is subtracted from the virtual work which the ball possessed; so that if the resistance equal to Q continued to be felt up to the center of the earth, the work effected would not be more than $Q \times 6{,}359{,}990$ instead of $Q \times 6{,}360{,}000$ kilogrammeters. When we have utilized the ten meters of fall above-mentioned, we have made use of a machine of which the useful effect is perhaps only 50 per cent., which is, however, very favorable. Every one will understand by a useful effect of 50 per cent. that we have utilized for some specified object $Q \times 5$ kilogrammeters. No one would take it into his head to say that the virtual work of the ball was $Q \times 6{,}360{,}000$ kilogrammeters; the power stored up is $Q \times 5$ kilogrammeters; therefore the useful

effect of the engine is $\frac{5}{6{,}360{,}000}$; that is to say, less than a millionth part. Every one will say I only arranged for a fall of ten meters and a weight of Q kilogrammes, and therefore only arranged for Q × 10 kilogrammeters, of which I have utilized Q × 5 kilogrammeters; therefore my engine yields a useful effect of 50 per cent. But if I wish to increase the work utilized, I must extend the limits between which the travel of the ball takes place. I must increase the distance from its starting-point to the center of the earth, or diminish that of its arrival at the same center; in a word, I must increase what I call the distance of fall. If, by any means of which I am possessed, I double this distance, and employ for its utilization the same machine as before, it will yield me 50 per cent. of the Q × 20 kilogrammeters which I have at disposal; that is to say, Q × 10. I shall have improved the fall, but not the machine; I shall have obtained more motive power, but only one-half of it will have become available as in the former case. Who will take upon himself to say the machine had before a power of $\frac{5}{6{,}360{,}000}$ and now the power is doubled?

I shall be told that these observations are too simple—too clear to be so much insisted on. But, if the reader will be so good as to follow me out, I feel convinced that he will alter his opinion in this matter. When, instead of a visible ball, there are an infinity so small that they are invisible, but which, combined, form a visible body—as, for example, a certain quantity of water—if all these molecules (balls, or what not, their form does not matter) have together a tendency to approach the same point—the center of the earth, there needs no abstraction to represent faithfully the phenomena of which we are going to treat. The proof is that in the case of water-wheels, it is said that the available force is equal to the weight of the water which falls, multiplied by the height of fall, or Q H; and if the wheel utilized U kilogrammeters, the power of the wheel is $\frac{U}{QH}$, and not $\frac{U}{Q \times 6{,}360{,}000}$.

As a starting-point for what follows, we will remark that U should be equal to its greatest value, Q H, if during the time of the water falling, the wheel oppose to it a constant useful resistance equal to Q. Such is the condition of the maximum of work given out theoretically. It cannot, however, be attained in practice for several reasons. In the first place, if the resistance is equal to Q, the water will not be able to fall, and there will be no motion. Then, to lead the water to the wheel it is necessary to borrow from the effective force of the water such a proportion as is necessary to overcome the friction against the sides and bottom of the mill-race. Then the water still retains its *vis viva* on leaving the race; that is necessary to it for this purpose. There are also eddies in the water; there are resistances; there is a visible friction between the molecules as they are carried towards the same outlets, which is transformed into invisible energy of the same molecules or of others, on their being hurried in partially different directions. There is also the friction of the wheel itself to be taken into consideration.

M. Lhoest's view is then perfectly consistent when it relates to a group of molecules, *possessing the power of transporting themselves altogether in one body towards the same point—the center of the earth.* But it is not correct, when the molecules seek their position of repose, one here and another there, each one to a determined spot. It is not, however, difficult to conceive that each of these, if it is free, goes to its point of repose, and passes that point to return after an oscillation, and so on continually, without its efficacious power being changed in any way—without its being augmented or diminished; but, on the other hand, if it is not free—if any resistance is opposed to its motion (a resistance smaller than its tendency to go towards its center of repose), a certain quantity of actual power is abstracted from it, which can be transmitted to an engine of a given horse-power; that the horse-power of this machine is quite independent of the proportion of the quantity of power abstracted to the actual power which the molecule might expend by the time it was brought to rest at its center of repose. Now, that which can be easily conceived of each molecule

taken separately, is entirely erroneous when these molecules are innumerable, and their centers of repose or attraction all different. It is, however, exactly the same phenomenon—the simplest of the phenomena of nature, and, I will even say, the sole phenomenon of nature ; it is the same law summed-up in the word *force*, and which points out the impossibility of generating or annihilating motion—the sole law of natural phenomena. The difference lies only in the way things are looked at, and especially in the names that are given to them. Let us make this clearer, in order to demonstrate the truth.

It is easy to conceive that with a certain resistance an isolated molecule can be led to its center of repose where it will remain, its ability to move being exhausted. Let it be imagined that the same phenomenon takes place in the case of each one of the invisible molecules of a body. Then, all the molecules of this body being in a state of repose, we express that their ability of motion has disappeared by saying that their temperature is at zero (absolutely). If, by any process whatever, instead of abstracting all motion from the molecules we only abstract a portion, we then say that there remains in the body a certain temperature ; a certain ability to move a certain actual power possible before it is brought to a state of repose, *a certain heat.* The absolute temperature of a body is the total mechanical power which is abstracted from this body if an available resistance equal to its attraction to its center of repose be opposed to each molecule, and that until each molecule has arrived at rest at its center of repose. This temperature can be expressed in kilogrammeters, naturally taking zero for a starting point ; to speak of negative temperature is absurd. But, inasmuch as everything here below is only relative, as we cannot materially realize the refrigeration of a body down to absolute repose, we have taken arbitrary temperatures for starting points, and have measured the actual power of a quantity of combined molecules in *calories*, each of which corresponds to 424 kilogrammeters.

If what we have just stated is quite understood, the rest will be easy to comprehend. I will suppose that we know the heat in kilogrammeters of a body, which we will consider to be P kilogrammeters, and that we have a scale of temperatures so graduated that t will correspond to the absolute temperature of this body. That signifies that if by resistance applied in a suitable manner to the molecules of the body, I were to abstract $\frac{P}{t}$ kilogrammeters from the force of which these molecules are capable, and if I were to repeat this operation t times, the body would be brought back into a state of repose. This quantity of work $Q=\frac{P}{t}$, which must be abstracted from a body to lower its temperature one degree bears the name of *thermic weight.* If, then, we cause the temperature to fall from t to t', we have abstracted from the body a force $Q\,(t-t')$, which can be turned to account by means of an engine. If this engine indicates 50 per cent., then the force utilized will be :

$$\frac{P}{t}\cdot\frac{t-t'}{2}.$$

But if, by means of an engine, we have withdrawn from a thermic weight $\frac{P}{t}$, by a fall of temperature $t-t'$, a force $\frac{P}{t}\,\frac{t-t'}{2}$, what can we say to anyone who tries to make us believe that the horse-power of the engine is equal to $\frac{P}{t}\,\frac{t-t'}{2}$ divided by the total work P, which would result in bringing each molecule of the body to a state of repose? But let us reduce to figures what has gone before.

If, by resistances suitably applied to the molecules of the body under consideration, we bring them together to a state of repose, and, consequently, the body itself to a temperature equal to zero, the force stored up will be 1,000,000 kilogrammeters (=P). The absolute temperature of the body we are considering was 500°; (= t = 273 + temperature C.) Each time, therefore, that we lower the temperature of the body 1° we abstract from it an available force of

$$\frac{1{,}000{,}000}{500} = 2{,}000 \text{ km. } (=Q).$$

If, in like manner, we lower this tem-

perature from 500 to 350°, we subtract 150 times the thermic weight, 2,000 kilogrammeters for the body, and, consequently, dispose of 2,000 × 150 = 300,000 kilogrammeters. If the engine which absorbs this force only gives out again in useful power 150,000 kilogrammeters, what is the horse-power of this engine? I say that it will be

$$\frac{150,000}{300,000} = 50 \text{ per cent.},$$

and I think that the reader will be of the same opinion. But up to the present time, with regard to thermic engines, people have taken quite another fashion, and have said, without, however, thoroughly understanding the matter,—a certain engine, working between temperatures of 500 and 350° (227° × 77° C.) with a million kilogrammeters only does a work equal to 150,000 kilogrammeters; therefore, its horse-power is

$$\frac{150,000}{1,000,000} = 15 \text{ per cent.},$$

and no notice is taken either of the amount of fall in temperature or of the relation of the initial temperature to that of absolute repose. In fact, this mode of reasoning would lead one to estimate the power of a water-wheel by dividing the power Q × 5 kilogrammeters, which it utilises, by the force Q × 6,360,000 kilogrammeters, which the weight of water, Q kilogrammeters, would produce by falling to the center of the earth.

It will be seen that it is quite time to proclaim everywhere that gross errors have been committed in estimating the horse-power of steam engines; that they have been calumniated; that we are mistaken in the things that require to be modified in our present practice in turning to account the work of that invisible attraction called heat; that we have given false returns; that we have attributed to certain stages that which has come back at others, and that, consequently, we have given bad advice to engine-builders. We will give an example of these false returns.

Let us take the steam engine on which M. Lhoest has made his experiments. No matter by what means, 593,956 calories have been given to the steam, and at that time the temperature of the steam is 193° C., or 466° absolute; so that the thermic weight supplied is, in kilogrammeters:

$$\frac{424 \times 593,956}{466} = 540,423 \text{ km.}$$

The source of cold is at 9.75° C., or 283° absolute. The fall in temperature that it is wished to utilize is then 466 − 283 =183°. The available power, being 540,423 kilogrammeters per degree of temperature, will, for a fall of 185° be

$$540,423 \times 183 = 98,897,500 \text{ km.}$$

That is what should be set down to the passivity of the engine, and is what it should give out again by a corresponding activity. This activity is composed, in the first place, of useful visible force given out, which is, according to the experiments, 424 × 76,524 = 32,446,176 km. What, then, is the horse-power of the engine? It is, as M. Lhoest put it,

$$\frac{424 \times 76,524}{424 \times 593,956} = 12.88 \text{ per cent.}$$

or rather,

$$\frac{424 \times 76,524}{98,897,500} = 32.81 \text{ per cent.}$$

The latter is the correct estimate of the power, and it is more than double 12.88. What matters it? will perhaps be said; the quantity of coal consumed is the same, and as that is the case what difference does it make that the power given out be really 33 instead of 13 per cent.? It matters, however, much as regards the construction of engines and the consumption of coal, for which so high a price is paid. In fact, the source of cold, the water of the condenser, was at a temperature of 9.75° C. or 283° absolute; if it had been possible to cool the steam to zero absolute, as 540,423 kilogrammeters go to a degree, a power of 540,423 × 283 = 152,939,850 km. would have been disposed of. And, since one cannot materially descend below 283° absolute, these 152,939,850 km. must be recovered from the water after condensation in order to have lost no available power. But 449,372 × 424 = 190,533,728 km. have been recovered from the water of the condenser, according to the experiments. There is, then, under this head, a loss of 37,593,878, that is to say, 38.01 per cent. of the useful power instead of 75.65 per cent.; and our process

of condensation is not so bad as M. Lhoest seems to imagine.

To what cause, then, must we attribute the losses we have just pointed out? Before answering this question, let us first reproduce the table of a few particulars concerning the engine. The second item reported by M. Lhoest gives, on our examination, 1.90 per cent. To recapitulate, then, we have :

	Per cent.
1. Work done by the engine.....	32.81
2. Loss of water in the casings. ...	1.90
3. Excess of heat found in the condensation water.....	38.01
	72.72
There remain then :	
4. For various causes	27.28

Why is an excess of heat to the extent of 38.01 per cent. found in the condensation water? The details given by M. Lhoest do not tell us this, any more, in fact, than the practice which exhibits it. It is to be regretted that experiments made with such precision should not have resulted in more detailed information. There are prejudicial spaces which in themselves constitute a source of loss ; the expansion is not sufficiently prolonged ; the admission of steam, the expansion and compression are not effected according to the rules for a maximum of power given out, &c. *What is the relative value of the causes of loss? To what extent can they be remedied?* Here are questions of the highest importance in practice, and which, I fear, experience alone is unable to answer. Theory must here lend her aid to the experimenter, even though he conceal his disdain for pure science under assurances of the greatest respect. But a full analysis of the steam engine has not yet been made, we do not pretend to make it ; we await that of M. Hirn, who tells us he is well up in the subject, and whose work advances rapidly. Some words of theory might, however, not be out of place here.

In order to store up the maximum of the power due to the fall of a body, the operation is easy to understand *that we should oppose to this fall a resistance always equal to the tendency of the body to approach its point of repose.* Then the body will reach this point, deprived of all speed, of all *vis viva ;* and, as it is impossible to annihilate or to create power, that which the body was capable of giving out at a certain distance from its point of repose is passed entirely into what has offered resistance to its motion. Undoubtedly, it is impossible to attain this maximum, if the conditions were practically realized, since, if resistance is equal to the power, motion would be impossible. But it is important to know the condition, even in order to appreciate the means to be employed to approach this as near as possible. Now, by what has gone before, it should be understood that means to use in thermic engines must be analogous to the foregoing. The principle is that the body which serves to transform the invisible motion of the molecules into one which is both visible and capable of being utilized (the steam in our engines) *is only found in contact with bodies which have the same temperature as itself*, that is to say, the same tendency to repose. The immediate consequences are :—(1) that this intermediate body always remains the same ; that it does not continually renew itself, as is done practically in our engines ; and, in consequence (2), that the admission of heat and its emission take place in the same receptacle ; (3) that the sides of this one receptacle are constantly at the same temperature as the steam which they contain ; (4) that during the time the body is in contact with the source of heat its temperature remains constant and equal to that of its source, and that it remains so during its contact with the source of cold ; (5) that, while the body returns from the source of heat to that of cold, its temperature falls on account of its dilatation, but within the receptacle at each instant to the same temperature, that is to say, without there being admission or emission of heat.

The diagram, then, of the evolutions of the pressure and of the volume of this body must be composed :—(1) of a curve of equal temperature during the admission of the heat (horizontal for the saturated steam, hyperbolic for the superheated steam) ; (2) of a curve of no transmission while the temperature of the steam falls from that of the hot body to that of the cold body ; (3) of a curve of equal temperature during the emission of the heat ; (4) of a curve of no transmission during the compression which re-

stores the temperature of the steam from that of the cold body to that of the hot body, and the steam itself to its previous state.

The diagram of admission should, therefore, not have a horizontal line to represent the superheated steam, and there should be a curve of compression. The expansion should be sufficiently prolonged for the pressure to become equal to that which corresponds to the temperature of the exhaust.

These conditions cannot be realized; very true; but what I want to know is the amount of approximation we can arrive at by practical means, and the amount of loss that can be fairly attributed to each imperfect method we adopt, in order to be enlightened as to the practice to follow so as to attain perfection. In this respect I am far from being satisfied even with M. Lhoest's table, after I have corrected it. Again, to what must we attribute the enormous loss of about two-thirds of the available power? To the worse than useless spaces; to the imperfect expansion; to the dead points of the stroke; to the necessity of leading the steam to the cylinder and afterwards to the condenser; to loss by radiation, &c.? To all these causes the reply must be, yes; but how much is to be attributed to each of them? That is the problem which science will one day solve.

A second also presents itself, which is none the less important as regards economy of fuel. One of the factors of the maximum available thermic power is, as we have seen, the fall of temperature, just as is the extent of fall in the case of a water-wheel. The other factor is the thermic weight. The available power of a falling stream of water from an orifice of given area, is augmented by increasing the height of fall. In the same way the effective power of a thermic weight is augmented by increasing the fall of temperature; viz., by raising the temperature of admission and lowering that of emission. The deduction from this is evident. This is the point to which attention should be directed in the first place—to extend as much as possible, within reasonable limits, the extreme degrees of temperature.

We cannot conclude these notes without referring briefly to the criticism with which M. Lhoest has honored us with respect to what we have said in our "Theory of Steam-Engines," as to the efficiency of steam casings. M. Lhoest admits that there is much controversy on this question; and in fact, that while the experiments of M. Hirn, M. Combes, and others, argue a saving of 20 and even 40 per cent. by the use of steam jackets, other experiments go to prove that there is no saving at all, if indeed there be no loss. It must, then, be conceded, that this is at present an open question; that it has not been settled practically; that the constructors of engines should not be counselled to adopt the steam jacket, looking to all the difficulties of unequal dilatation and consequent fracture which often ensue; in a word, that the whole question of steam casings should be reserved for the present. I entirely share M. Lhoest's views, when he expresses the opinion that the efficiency of the casing depends on special conditions in particular cases; this must be so, as the problem remains without solution in practice. But, I confess, I have difficulty in crediting a saving of 40, and even of 20 per cent., in particular cases, *since no reason can be assigned for the existence of such saving* in these particular cases. That there may possibly be a saving of 5, and even 10 per cent. in daily practice, I admit; but 20 and 40 per cent. I cannot believe, the concurrence of so high an authority as M. Hirn notwithstanding.

In no experiment has the speed of the engine been taken into account; and yet I have already shown that, according to this speed, the power might vary from zero to a maximum following a series which, at certain points removed from the maximum, varies with extreme rapidity. Now I am convinced that the speed of our steam engines differs considerably from that which corresponds to the maximum of power given out. Is, then, this matter unimportant, since the power of the engine is even treated differently to that of a fluid? The question of steam casings cannot be determined experimentally, more than any other, unless every thing be taken into account in the experiments, which is impossible. It is, then, in my opinion, desirable to have the matter elucidated by the aid of

theory, instead of experiments, which often lead the experimenter astray into a labyrinth of influences, which he does not understand, and which give to his deductions the appearance of impossibility or erroneous interpretations, while the results themselves may be without question.

THE PROPOSED SUBMERSION OF NORTH AFRICA BY THE MEDITERRANEAN SEA.

From "Journal of the Society of Arts."

After a brief notice of the traffic in foreign merchandise that passes through the Tunisian port of Susa, for distribution by means of caravans amongst the towns and villages of the interior, Vice-Consul Dupuis remarks more fully upon the projected inland North African sea. The project of submerging the region of Djerid by means of a canal is based upon a fact clearly recorded, viz., the presence of water, in the form of lakes, in the line of the great depressions, and upon the presumption that these lakes were themselves but the residue of some vaster body of water or inland sea, which disappeared at a still earlier date from the surface, owing, it is conjectured, to the formation of an isthmus, which cut it off from the Mediterranean with which it was connected.

The recent surveys, though they reject the idea of any connection with the Mediterranean having existed—a hasty conclusion based upon mere inferiority of level to that of the sea—would seem to indorse the fact of all the region having been under water. Indeed, had there existed a connection, it is presumable that more than a mere incidental reference would have come down to us regarding so large an arm of the sea, as in that case it would have been indenting the land, and therefore available for the purposes of war or commerce by the ancients. The results obtained prove that the sands are of but secondary importance on the isthmus, which is chiefly composed of alternate strata of grey quartz and ferruginous freestone, which rise at an angle of sixty degrees, and lie over another stratum of chalk. This excludes all notion, therefore, of any choking up of an early passage for the waters. No reference is made to waters in the depressions by Arab writers, probably on account of their insignificance at the date of their conquest, yet all unite in describing this country as having been very woody, but state that the wood was all cut down to facilitate the subjection of the tribes, who, for upwards of a century after, fought desperately for their independence, as well as during their own internecine wars which followed. According to them the country was well supplied with streams and abundance of water, a statement itself in harmony with the notion of a degree of atmospheric humidity conducive to luxuriant vegetation, and presupposing the cause which alone could bring it about.

Whole regions, therefore, now condemned to sterility, with, save perhaps an oasis here and there, were formerly rich in pastures, and interspersed with towns. The desert, which has gradually extended in regions lying between Tripoli and Egypt until it has reached the sea, covering districts once fertile, and burying Egyptian ruins, has, beyond doubt, similarly encroached on the Tunisian southern frontier between it and Tripoli. The diminished heights and lowering of the Atlas range, let in the sands carried by every southerly wind, notably by the periodical south and south-east winds, to which the more elevated and uniform heights of the mountain system oppose a formidable barrier in more favored Barbary States westward. In Morocco, especially, these same winds are so tempered in their passage across the intervening heights as hardly to be recognized as the same which here dry up and parch the land in summer. It may therefore be presumed that the disappearance of the waters in question is due to the encroachment of the desert, caused by the action

of these winds during a long succession of centuries, aided by absorption and by co-operation occasioned by the presence of the vast scorching desert to which their own southern aspect left them fully exposed. To these causes may also be added the substances brought down by streams, which, by all accounts, were many; these, by narrowing the margins and spreading the waters, helped the work of desiccation, which was accelerated, moreover, by a decrease in the pluvial supplies consequent on the disappearance of mediæval forest. There can be no doubt about the drying up of many of the streams here, as elsewhere in Barbary, being due to the clearing away of forest, whether in the plains or in the highlands, by the Arabs on their conquest and after. The consequence is that the periodical rains, which at an earlier date fertilized the country, were replaced by heavier but rarer falls, the waters of which rush down the slopes and disappear in the sands, or mix with the noxious waters of the lagoons ere they penetrate and salinate the soil to any depth. The action of these passing waters is seen in a wasting away of earth and exposure of naked rock in all the "Hamayed," or elevated lands, hill sides, or ravines.

When it is considered that the regency of Tunis is a lake country, and that recent discoveries have brought to light similar vast sheets of water in Africa, the existence of an inland sea may not seem such a startling idea.

THE CALCULATION OF EARTHWORK.

By N. B. PUTNAM, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

A SECTION of earthwork is a solid, bounded by the formation surface or road-bed, the side-slopes, the two planes of cross-section and by the natural surface of the ground—a surface generally curved and more or less irregular. For the determination of the cubical content of this solid, there are given its length, or the perpendicular distance between the cross-sections and the two end or cross-sectional areas, which are usually determined by the width of the road-bed, the value of the side-slopes, and by the center and side heights.

The two modes of calculation most frequently employed in estimating earthwork, are: 1°, the Mean Areas Method," in which the section of earthwork is regarded as equivalent to a prism, the area of whose base is equal to the mean of the two end areas, and whose altitude is the length of the section; so that if S_1 and S_2 be the end areas, and l the length of the section, the solidity will be represented by

$$V_1 = \frac{S_1 + S_2}{2} l \quad . \quad . \quad . \quad . \quad . \quad (1)$$

2°, the method by the Prismoidal Formula, which (*a*) regards the solid under consideration a prismoid, *i. e.* a solid composed of prisms, wedges and pyramids whose common altitude is the length of the section, or which (*b*) assumes the natural surface of the ground to be a surface generated by a right line moving along the surface lines of the two cross-sections; by this method the content of the section is represented by

$$V_2 = \frac{l}{6} (S_1 + 4\, S_m + S_2) \quad . \quad . \quad (2)$$

in which S_m is the "*middle area*," and is (*a*) equal to the sum of the middle areas of the prisms, wedges and pyramids of the prismoid, or it is (*b*) the area of an assumed cross-section, any "height" of which is the mean of the corresponding heights of the end cross-section. The Prismoidal Formula, with an assumed middle area, is the basis, so far as I am aware, of all the many "Earthwork Tables" in common use.

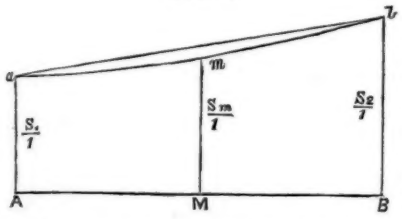
From eqs. (1) and (2) we see that V_2 will equal, be greater or less than V_1, according as S_m is equal to, greater or less than $\frac{S_1 + S_2}{2}$. In this article we shall assume the middle area to be less than the mean area, since statements not unfre-

quently appear in engineering text-books to the effect that this method of calculation by the Prismoidal Formula gives the true quantity of excavation or embankment, while the amount of earthwork, as estimated by averaging the end areas, is generally too great.

In order to present at a glance the solidity of a section of earthwork, let us substitute for it an equivalent solid whose altitude is an unit; the base of such a solid will contain as many units of area as the solid contains units of content; and the formula which expresses the area of this base may also be used to determine the solidity of the section.

Let A B (Fig. 1) represent the length of a section, let S_1 be the cross-sectional area at A, S_2 that at B, and let $S_2 > S_1$.

Fig. 1.



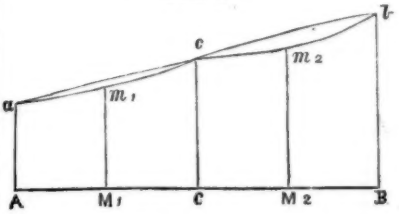
At A erect a perpendicular A a, representing as many units of length as S_1 contains units of area; so also let B b represent $S_2 \div$ unity; join $a\,b$; the area of the base A $a\,b$ B is $\frac{S_1+S_2}{1} \cdot \frac{l}{2}$, which being multiplied by unity gives the cubical content of the section as found by the Mean Areas Method. At M, the middle point of A B, erect a perpendicular M m representing as many units of length as the assumed middle area contains units of area; join $a\,m\,b$; the area of the base A $a\,m\,b$ B, found by the well-known Simpson's Rule, is

$$\frac{l}{6}\left(\frac{S_1+4\,S_m+S_2}{1}\right)$$

which is the form of eq. (2).

Suppose, now, that we have three equidistant cross-sections, S_1, S_2, S_3, the first taken at the foot of a hill, the third at the summit, and the second midway between the third and first; S_2 will evidently be greater than $\frac{S_1+S_3}{2}$. In (Fig. 2) let A B represent the distance between the end cross-sections, let A a represent $\frac{S_1}{1}$, C c, $\frac{S_2}{1}$ and B b, $\frac{S_3}{1}$; join $a\,c\,b$. Since the area of the base of this

Fig. 2.

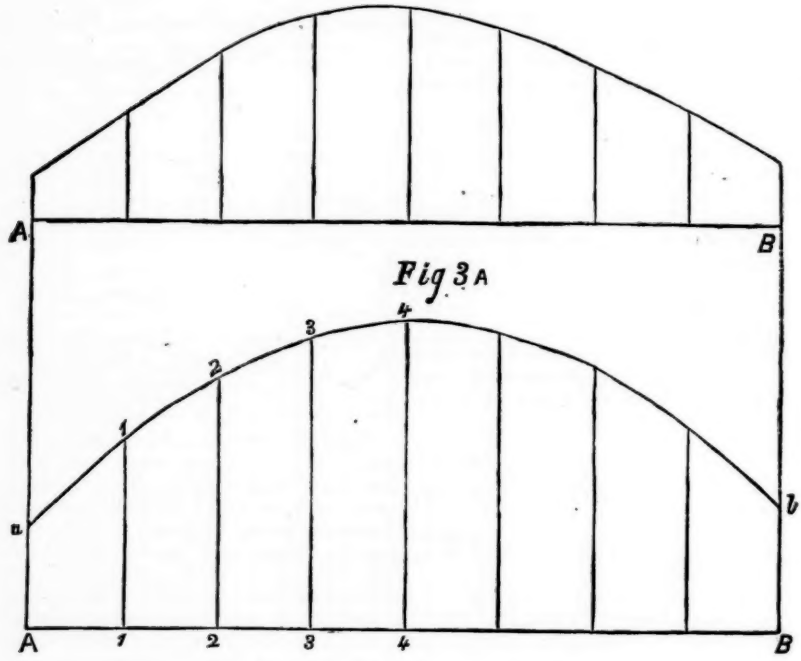


equivalent solid is given by Simpson's Rule, the solidity of the block of earthwork may be found by the Prismoidal Formula, using S_2 as the middle area.

Consider now the two sections into which the middle cross-section divides the block of earthwork. The amount of excavation, as found by the Prismoidal Formula, using assumed middle areas may be represented by the area A $a\,m_1$ $c\,m_2\,b$ B; $M_1\,m_1$, $M_2\,m_2$ representing the assumed middle areas. We thus obtain two entirely different results, although both methods of calculation are based upon the same form of expression; the error arises, not from the first application of the Prismoidal Formula, but from the use of the assumed middle areas $M_1\,m_1$, $M_2\,m_2$; that is to say, a section of earthwork is not a prismoid, nor is the surface of the ground a surface of right line generation.

To present the case more clearly, let (Fig. 3) represent the longitudinal section of a cut or, inverted, of a fill, the surface line being concave towards A B, and suppose that the work has been cross-sectioned at every foot of its length; the cross-sectional areas will vary as the ordinates of the curve a 1 2 3 . . . b (Fig. 3A) which is convex or concave according as the surface line (Fig. 3) is convex or concave. Construct as before the base (Fig. 3A) of an equivalent solid of unit altitude; knowing the general form of this base, and having given a number of cross-sectional areas, and the distances between the points at which these areas are measured, we can determine what method will best give the amount of excavation

FIG. 3.



or embankment. From (Fig. 3A) we see that the Mean Areas Method gives *less* than the true amount and more than the method of the Prismoidal Formula, using assumed middle areas.

In the exceptional case of an excavation through a valley or an embankment over a knoll or hill, the line $a\,1\,2\,3\,\ldots\,b$ in (Fig. 3A) will be convex downwards; the Mean Areas Method will in this case give an estimate a little too large, while the Prismoidal Method will give nearly the true amount of earthwork.

When the cross-sections are equi-distant, the solidity of the excavation should be found by the Prismoidal Formula using measured middle area; in other words, by the application of Simpson's Rule substituting the cross-sectional areas for the length of the ordinates.

Let n = the number of equi-distant cross-sections, and l the common length of the sections, the volume of earthwork is given by the following equations:

$$n \text{ odd, } V=\frac{l}{3}[S_1+4S_2+2S_3+4S_4 +\ldots\ldots+4S_{n-1}+S_n]$$

$$n, \text{ even, } V=\frac{l}{3}[S_1+4S_2+2S_3+\ldots\ldots +4S_{n-2}+S_{n-1}]+\frac{l}{2}[S_{n-1}+S_n]$$

With very irregular ground the best approximation is given by the Mean Areas Method.

A TELESCOPE is now in course of construction, in Dublin, by Messrs. Grubb, for the Vienna Observatory. The telescope is to be thirty-two feet in length, and it will have an object glass of twenty-six inches diameter; the large brass case, weighing eight tons, is to have a chamber twelve feet in length, and four and a-half feet in diameter. The tube is to be entirely of steel, and all friction of the axes will be avoided. The instrument is to be finished in the course of 1878; its cost is estimated at £87,500.

SOME METHODS OF ESTIMATING THE ILLUMINATING POWER AND PURITY OF COAL GAS.

By A. VERNON HARCOURT, M.A., F.R.S.

From "Journal of the Society of Arts."

It is well known that coal gas which has been purified from sulphuretted hydrogen is not free from sulphur, but retains, chiefly in combination with carbon, a quantity of this element, varying from ten to forty grains in 100 cubic feet. It is commonly believed that the small quantities of sulphurous and sulphuric acid produced by the burning of coal gas distinguish it unfavorably from other illuminants, and hence there is a general wish among both the consumers and producers of gas to remove as far as possible the last traces of sulphur.

Sulphuretted hydrogen is one of the few substances for whose presence, even in very small quantity, we have a test which anyone can apply, which is quick and conclusive. The existence of such a test has no doubt contributed greatly to the development of a system of purification, by which coal gas, at least in London, is always and absolutely freed from sulphuretted hydrogen. In his endeavor to purify gas from other sulphur compounds the manufacturer has no test so handy as the strip of lead-paper, to bear witness at once when the purifying material needs renewal. Increased facility of testing might lead, in this case also, to the discovery of better methods of purification or to a better management of existing methods.

While endeavoring to turn to account for the purification of gas the effect of heat upon it, which converts the bi-sulphide of carbon in gas into sulphuretted hydrogen, it occurred to me that a test might be based on the same principle.

I have here a glass tube filled for two inches with a plug of platinum wire and foil. I am passing gas through it, but as the gas is pure from sulphuretted hydrogen it does not affect the paper moistened with solution of acetate of lead upon which the gas is blowing. Now I heat the tube, and you will soon have evidence of the presence of sulphur in the gas.

This, however, is only a qualitative test, or, at most, the rate at which the paper darkens furnishes a very rough indication of the amount of sulphur in the gas. In the case of an impurity such as sulphuretted hydrogen, which is to be wholly removed, a qualitative test of this kind is all that is required. But, as no means are known of arresting completely the other compounds of sulphur, and all that can be done is to reduce their proportion as low as possible, a qualitative test is insufficient. What is required, as a guide in managing the process of purification, is a rapid quantitative test.

To fulfill this requirement, I propose to substitute, for the lead-paper with the gas blowing upon it, a solution of lead, through which the gas shall pass in small bubbles. All the sulphuretted hydrogen in the portion of gas operated on is thus arrested; and, through the mixing of the liquid, an uniform color is obtained, whose shade the eye can compare with that of a similar portion of a standard colored liquid. If the passage of the gas is continued until the tint, which grows continually darker, matches that of the standard liquid, a definite and ascertainable quantity of lead sulphide must have been formed, containing a known quantity of sulphur, and that derived from a known volume of gas. The larger the volume of gas that must be passed before this tint is attained, the smaller, in exact inverse ratio, is the proportion of bi-sulphide of carbon in the gas.

To prepare a lead solution which gives a clear tint instead of becoming turbid when acted on by sulphuretted hydrogen, I dissolve litharge in caustic soda, and add a relatively large quantity of solution of sugar. For each testing, a little of the solution thus prepared is mixed with twenty or thirty times its volume of water.

For a standard of comparison, I have tried various coloring matters. Any red, yellow, and blue seem to give a brown.

Cochineal, caramel, and indigo, rightly proportioned, matched the tint of the colored lead solution very satisfactorily; and the appearance of the liquid did not change perceptibly from day to day; but, after some weeks, I found that my result had varied, and that the gradual fading of the standard color was the cause. Since then I have used a mixture of the three sulphates of copper, cobalt and iron, substances which are perfectly stable. To imitate a dark shade which the colored lead solution has, probably owing to the sulphide of lead not being really dissolved, but rather suspended in a state of minute division, I add a trace of lamp-black to the standard liquid.

Unfortunately, the colored lead solution and the standard look differently by day-light and by gas-light, and, through the change of light, they become extremely different one from another. I have, therefore, prepared another standard for use by gas-light, and it happens conveniently that a mixture of the sulphate of cobalt and copper serves the purpose.

The volume of gas which has been operated upon is known with sufficient accuracy by reading off the volume of water which has run from the aspirator into the measuring vessel placed beneath. The standard has been made such, that to impart the same tint to the same volume of lead solution, there is required 0.0025 grain of sulphur. From this datum, and the capacity of the measuring cylinder, I have calculated a table giving the number of grains of sulphur in one hundred feet of gas corresponding to each graduation.

The apparatus in the form in which I have it here is probably familiar to some who are present, as I brought it before the meeting of the British Association of Gas Managers at Leeds last summer, and my account of it was published in the *Journal of Gas Lighting*. But quite recently a suggestion made to me by Mr. Wills has led to an improvement in the apparatus, which may, I hope, help to justify me in giving this further account of it.

Mr. Wills suggested to me to use platinum as the heated material over which the gas should pass, he having observed that the development of sulphuretted hydrogen occurred at a lower temperature when the gas was in contact with platinum, then when it is heated otherwise.

Such an action of platinum upom mixtures of gases is familiar to chemists by many examples, and I can only plead in defence of the comparatively bulky and inconvenient form which my test has assumed hitherto, that I designed it, in the first place, not for laboratory use, but to illustrate a chemical fact, which I hoped to turn to account on a large scale for the purification of gas. Those who have used it must, I think, have convinced themselves that when gas is passed through a layer of heated pebbles, the sulphur contained in it, with the exception of 8 or 9 grains in 100 cubic feet, is converted into sulphuretted hydrogen, and can, therefore, be easily removed.

If any others have had this test in operation, as I have, continuously for several months, they will also have convinced themselves that the action of the heated surface upon the gas may be continued for an indefinite time, if the temperature is not allowed to rise too high, and if, at intervals of one or two months, air is drawn through the apparatus.

Experimenting with this larger object in view, I made trial only of common materials, which it was practicable to use on a large scale. Perhaps it is impossible that so costly a metal as platinum should be used in gas manufacture, especially where the object in view is only a slight improvement in the quality of the article manufactured. But it is possible to employ costly materials for common uses where, as in the use of gold on paper-hangings, a little goes a long way. Substances which can be dissolved, may be spread over an indefinitely large surface, by wetting the surface with their solution. Mr. Deacon has thus applied copper to the manufacture of chlorine. Whether or not the action of heated platinum on gas may hereafter find any more extended application, it serves exceedingly well the purpose of this test. It may be used by leading gas through either a piece of glass tube packed with platinum wire, or a bulb filled with pumice which has been steeped in chloride of platinum and ignited.

I have now in the second place to direct your attention to certain methods of estimating the illuminating power of

coal gas. Such methods divide themselves into two kinds; those in which the amount of light obtainable from a given volume of gas is, by some means, directly estimated, and those in which it is inferred from some other property of the gas.

Of the latter, which I may call indirect methods, one of the best, but the most troublesome, is the complete analysis of the gas. This demands a special and somewhat complicated and fragile apparatus, and considerable manipulative skill on the part of the operator. Improvements in the methods of gas analysis have considerably reduced the length of the operation, but it can hardly occupy less than three or four hours.

Some information, but of rather uncertain value, is to be derived from the determination of the specific gravity of the sample of gas.

Absorption by bromide of the olefines, to which chiefly the illuminating power of gas is due, is an operation which can be easily and quickly performed, and which should give trustworthy, though not very exact, indications of the relative value of different samples of coal gas.

The simplest and most trustworthy of the indirect methods are those which depend upon the relation between the quality of different samples of gas burning under the same conditions, and the size of the flame which they produce. The size of the flame is most easily observed by giving it the form of a long, narrow column as in Lowe's jet photometer. The samples of gas to be compared may be burnt when issuing either at the same pressure, or at the same rate. Or else the length of flame may be kept constant and the required pressures or rates of consumption compared. The last-named modes of operation are those employed in Messrs. Kirkham and Sugg's form of the jet photometer, and in the "duration" test. Still another mode of making the same comparison has recently been proposed by Mr. Sugg, who has been kind enough to lend me his illuminating power meter to show here this evening. In this instrument the gas is set to burn from an Argand burner with a flame three inches in height. It can be made either to pass through the meter or not; and in the upper part of the meter case is a minute clock. The index of the meter having been stopped at the top of the scale, gas is sent through the meter for one minute by the clock, and then turned off again, the flame being constantly maintained at the height of three inches. According as the gas is richer or poorer, the index of the meter will have traveled a less or greater distance; and the dial-plate is so graduated and numbered, that from the place at which the index has stopped, the illuminating power of the gas may be read off.

Direct observations of the illuminating power of different samples of gas have hitherto been made by a judgment of the eye, comparing under conditions favorable to exact observation the relative brightness of the flame produced by the sample of gas and of a standard light.

Within the last year, however, two substitutes for the direct judgment of the eye have been suggested, founded upon the observation of two physical properties of light. The facts which have been observed in both cases are of transcendent scientific interest; but I must here confine myself to the proposed practical applications of them to photometry.

The element selenium is a substance so incapable of conducting electricity that it has been used as an insulator in telegraphy. Three years ago Mr. Willoughby Smith observed that its power of insulation was impaired by exposure to sunlight. Since then this effect of light has been examined by Dr. Werner Siemens and Professor Adams.

Unfortunately the effect of light upon the electric conductivity of selenium varies according to the temperature to which the selenium has been exposed, and the mode of cooling; moreover the effect of light gradually diminishes, and after prolonged exposure the selenium needs to rest in darkness for a length of time before its sensibility is fully restored. The most comparable results are obtained by observing the maximum effect produced when a piece of selenium, inserted in a galvanic circuit, comprising a battery and a galvanometer, is exposed to various sources of light for a few moments. Professor Adams employs a piece of crystalline selenium which is exposed to different sources of light suc-

cessively, for ten seconds, and observes the maximum deflection of the needle of the galvanometer. Dr. Siemens arranges the ends of two fine wires in a spiral or zigzag form, so that within a small space each may be close to the other, without touching, for a considerable length. By covering the interlacing spirals or zigzags with a drop of molten selenium, pressed into a thin sheet between two leaves of talc, the wires are connected throughout this length by a surface of selenium.

The sensitiveness of the selenium element thus prepared is admirably shown by an apparatus designed by Dr. C. W. Siemens, which he has kindly lent me for this evening. In it the selenium element plays the part of the retina of the eye; in front of it is a lens to bring the rays of light to a focus upon it, and beyond this a pair of metal eyelids closing by a spring, which preserves the selenium retina from the fatigue it would experience if constantly exposed to light.

Dr. Werner Siemens compares the light from two sources by so adjusting their distance from the selenium disc that, when it is exposed to each in rapid succession, the deflection of the galvanometer remains unchanged.

Selenium thus employed is said to be unaffected by the obscure heat rays, but to be affected by the red end of the spectrum in a greater degree than corresponds to the impression produced by that part of the spectrum upon the human eye. This defect may be remediable, as Dr. Siemens suggests, by interposing a sheet of glass with a green tinge. But a difficulty which must be overcome before any physical effect of light is accepted as a substitute for its impression upon the eye, is that of proving an exact correspondence between the physical and optical effects.

This vacuous globe containing the finely poised discs, which revolve rapidly when brought near a lamp, has already become familiar. It is called by its inventor, who is also the discoverer of the repulsive force exercised by radiant heat and light, a radiometer. Mr. Crooks has ascertained that the difference between the repulsive effect exerted upon the black and white surfaces of the discs, respectively, as measured by the rate of rotation, varies directly with the amount of light or radiant force falling upon them. Two candles, for example, at any given distance produce twice the rate of rotation which is due to one, and the effect upon the instrument of a given light varies inversely as the square of its distance.

But in this case, much more than as affecting the electric conductivity of selenium, radiant light needs to be separated from radiant heat, before the motion due to its repulsive force can be employed as a measure of illuminating power. Through the kindness of Mr. Crookes, I am able to show you the instrument which he has devised for comparing the amounts of light, separated from the rays of greater and less refrangibility, issuing from two or more sources. A pith beam, suspended horizontally in a vacuous globe by a single fibre of silk, is blackened on both sides, for half its length. When light falls upon one side of this beam, the blackened half recedes, and in the absence of other forces, the beam would set itself with its white end pointing towards the light. To the center of the beam are attached, in a transverse direction, a small magnet and mirror. The former serves, when a magnet is placed beneath the apparatus, to make the beam assume a particular position, from which it can be displaced more or less, by the incidence of a stronger or weaker light on one side, but to which it returns when no longer solicited by other forces. The latter serves, by reflecting a pencil of light on to a scale some distance off, to render evident a small displacement of the beam. If two sources of light are placed on each side of the beam, such and at such distances that no displacement occurs, the amounts of radiant force emanating from each and acting on the two sides of the beam are equal. In order that the forces thus compared may be due to radiant light only, two glass cells with parallel sides are filled with solutions of sulphate of quinine and of alum, to cut off the invisible rays at each end of the spectrum.

Errors of observation in judging of the relative brightness of the two sides of a partially translucent disc may hereafter be got rid of by the adoption of one or other of the methods which I have attempted to describe. But two

problems remain, a satisfactory solution of each of which is more necessary to the establishment of a trustworthy system of photometry than the substitution for the disc of some more absolute criterion of illuminating power.

The first problem is, what standard shall be used for the measurement of artificial light; the second, what burner shall be used in testing the illuminating power of coal gas.

The present unit, as defined by Act of Parliament, is a sperm candle of six to the lb., burning 120 grains an hour. This is convenient as an unit, since the light given by different lamps and gas-burners may be described, without the use of high numbers or of decimals, as a light of 10, or 15, or 20 candles. But without further definition it is by no means satisfactory as a standard, since the light which a candle gives depends not only upon the material of which it is made and the rate at which it burns, but also upon the construction of the wick. Some differences of opinion exists among those experienced in candle photometry as to the extent of fluctuation to which the results thus obtained are liable. According to my own experience, sets of observations made one after the other with the the same sample of gas, and with candles from the same packet, often agree very closely, and seldom differ to the extent of one candle. Occasionally, however, without any apparent cause, the results are more divergent; and I have found a considerable difference in the results and in the degree of uniformity with different packets of candles obtained from different dealers. What the burner is to gas, its wick is to a candle; and just as the definition of the illuminating power of gas has been unsettled by improvements in the burner used for testing, so it may also be altered by the application of similar attention and skill, on the part of the candle maker, to the conditions under which the maximum illuminating power can be developed from the combustion of 120 grains of sperm per hour.

If it be possible, as I hope to show that it is, to furnish a more constant standard of comparison for artificial lights than the sperm candle, the term candle might still be retained as the name of an unit otherwise defined, just as "foot" has come to be the name of an exact measure.

In Paris the photometric standard is the Carcel lamp, burning colza oil at a given rate. Some years ago Mr. Keates proposed the use of sperm oil, and I understand that such a lamp has recently been constructed on an improved principle by him and Mr. Sugg. I have not personally made trial of any of these lamps, but probably they give a light more constant and more comparable with that of a gas flame than is the light given by a pair of candles. At the same time, the very fact that an improved form of lamp has recently been constructed—if, as I believe, the improvement relates not only to the constancy but to the illuminating power of the lamp—suggests the likelihood that one standard lamp might differ in some degree from another, and that further improvements might gradually creep in. With a lamp, as with a candle, the wick is a most important element, and one which it is exceedingly hard to fix or define.

It was to meet the uncertainty as to the construction of the wick—and also that as to the composition or purity of the liquid fuel—that Mr. Crookes devised this little lamp which he has kindly lent me. Its wick consists of a certain number of platinum wires of a certain size. The liquid which burns is a mixture of two pure substances, alcohol and benzol. The light is said to be much more constant than that of a candle; but the flame in its present form is too small to be conveniently compared with that obtained from gas burning at the rate of five cubic feet an hour.

At present, I think it must be admitted that the problem of devising a satisfactory photometric standard, which can easily be obtained at different places, and is easily applied, and is such that when prepared with due care absolute confidence may be placed in its uniformity, has still to be solved.

Upon this problem I have been working at intervals during the last two or three years; and though I am still occupied with the work and have not yet completed it, I may be permitted to lay before you the results at which I have arrived, and to show what would be the operations required for testing the illumi-

nating power of coal gas under the system which I propose.

In place of candles or lamps I propose to use a standard gas. As no single gas exists which is suitable, a mixture of gases must be employed; and that which I believe to be most suitable is a mixture of hydrogen with pentane or with pentane and hexane. The two substances last named constitute the most volatile portion of American petroleum. Under a pressure of one atmosphere pentane is a liquid at temperatures below 30° C., and hexane at temperatures below 68° C.; but under under a pressure of one-tenth of an atmosphere, and probably under somewhat greater pressures, both these substances are gases. To reduce the pressure upon them, and also to reduce their illuminating power to that of ordinary coal gas, they must be mixed with another gas. I have tried both air and hydrogen for this purpose, and I prefer hydrogen for the following reasons: A smaller quantity of petroleum, in about the proportion of two to three, is needed with hydrogen than with air for the same illuminating power, and thus the petroleum gas is under a less pressure, and further from its point of condensation. The gas prepared with hydrogen has about the same specific gravity as coal gas, and therefore, presumably, the same burner is suitable for both, whereas the gas prepared with air is, of course, heavier than air. In preparing the standard gas with air, a meter must be used to measure its volume, and corrections applied for the variations of barometer and thermometer; whereas by acting on an excess of zinc with a known weight of sulphuric acid, a quantity of hydrogen is obtained, which is accurately known without the need of either measurement or correction.

The following, according to Cahours, are the constituents of petroleum boiling below 100° C.:

Pentane, sp. gr. at 17° C., 0.628, boiling point, 30°.

Hexane, sp. gr. at 16° C., 0.699, boiling point, 68°.

Heptane, sp. gr. at 16° C., 0.6995, boiling point, 92° to 40°.

Starting with the lightest pretroleum which is obtainable commercially, I have rectified it with the following results. The composition of the samples is calculated on the supposition, which is probably nearly correct, that by rectification below 65° heptane may be excluded.

Petroleum rectified

below 45°	sp. gr. at 15°, 0.635
45°—55°	sp. gr. at 15°, 0.647
55°—65°	sp. gr. at 15°, 0.664
below 65°	sp. gr. at 15°, 0.646

Composition of samples:

	Below 45°	45°–55°	55°–65°	Below 65°
Pentane ..	82.9	53.7	12.2	56.1
Hexane...	17.1	46.3	87.8	43.9

The proportion of hydrogen which must be added to the hydrocarbons to produce gas of constant illuminating power will vary slightly according to the composition or specific gravity of the sample of petroleum employed. It is on this point chiefly—a point of capital importance—that I need still to make further experiments. I have worked chiefly with the sample whose specific gravity is 0.646.

To prepare standard gas I employ the following apparatus: A flask of from three to four litres capacity, into the mouth of which a thistle-funnel and elbow-tube pass through a plug of india rubber; a wash-bottle of about a litre capacity; a gas-holder capable of containing seven or eight cubic feet; one or more graduated vessels for measuring out the required quantity of dilute sulphuric acid; a Winchester quart, fitted with pinchcock and inlet tube for air, to hold the measured quantity of acid and deliver it by degrees into the generating flask; a pipette of seventy or one hundred cubic centimeters capacity, to measure the required dose of petroleum, and deliver it into the wash-bottle.

The operation of preparing standard gas is as follows: The flask is filled one-third with granulated zinc, and connected with the wash-bottle, two-thirds of which is filled with water. About one hundred cubic centimeters of dilute acid is first poured upon the zinc, which generates sufficient hydrogen to sweep out air from the flask. When the evolution of hydrogen has ceased, which requires about half an hour, the wash-bottle is opened and the pipetteful of petroleum discharged into it, after which the wash-bottle is at once closed and connected with the gasholder. The Winchester quart, holding the measured vol-

ume of dilute acid, is supported in an inverted position, and its pinchcock is so adjusted that the acid may flow in a rapid succession of drops into the generating flask. Hydrogen passes in a rapid stream through the water in the wash-bottle and through the layer of petroleum which floats upon the surface of the water, and the mixed gases pass on into the holder. From this point the operation needs no further attention. When all the acid has run in, the evolution of hydrogen gradually diminishes, and almost ceases by the time that the liquid, heated by the action, has become cold. The gasholder then contains the whole of the petroleum which was taken, and a quantity of hydrogen which is also exactly known, since the sulphuric acid has saturated itself with zinc, and consequently has yielded one-forty-ninth its weight of hydrogen.

The water in the wash-bottle serves to prevent any acid spray passing to the holder, to provide a level floor for the evaporation of the petroleum, and to furnish the heat which the petroleum needs to pass from the liquid to the gaseous state. The absorption of heat, as the petroleum volatilizes, reduces the temperature of the contents of the wash-bottle considerably below that of the surrounding air. Consequently the standard gas is formed at a temperature below that to which it is afterwards subjected. In spite of this reduction of temperature, the whole of the petroleum has generally disappeared when two-thirds of the hydrogen has passed over. Consequently the standard gas is formed under a pressure exceeding by at least one-fourth that to which it is afterwards subjected. It is therefore a permanent gas under any conditions to which it is likely to be exposed.

I have here two similar tubes, standing vertically in a vessel of water, which have been filled to the same level, one with air, the other with standard gas. When ice is placed around them, so that their temperature falls to 0°, the contraction is the same in both cases, showing that the standard gas behaves like a permanent gas, and that no liquid petroleum is condensed out of it.

The dilute sulphuric acid which I have employed has the specific gravity 1.217, and contains 0.352 grains of pure sulphuric acid in one cubic centimeter. It may be made, approximately, by mixing 26.5 volumes of oil of vitrol with one hundred volumes of water. The strength of the dilute acid is unimportant, provided it be exactly known, and provided that it is not such that sulphate of zinc crystallizes out and hinders the action of the acid.

It will be seen that the adjustment of the illuminating power of the gas is thus practically brought, with an acid of known strength and a particular sample of petroleum, to a question of rightly proportioning the volume of acid to the volume of petroleum. The following are some of the results I have obtained with acid of the above-mentioned strength and petroleum distilled below 65° and having the specific gravity 0.646. The numbers given under the head of illuminating power are in most cases the mean of four or five different sets of observations made with different samples of standard gas prepared according to the same recipe.

Vol. of Dilute Acid. Sp. Gr. 1.217.	Weight of Pure Sulphuric Acid.	Weight of Hydrogen.	Weight of Petroleum.	Ratio of Petroleum to Hydrogen by Weight.	Illuminating power (candles).
c c.	Grams		Grams		
1680	593	12.07	45.22	3.75	14.5
1640	579	11.78	"	3.84	15.2
1615	570	11.6	"	3.9	15.9
1610	568	11.57	"	3.91	15.97
1605	567	11.53	"	3.92	16.1
1580	558	11.35	"	3.98	16.6

Hence it appears that a mixture of one part by weight of hydrogen and 3.91 parts by weight of light petroleum, form a gas of sixteen candles' illuminating power. I propose the use of this gas as a photometric standard. It consists of 90.9 volumes of hydrogen and 9.1 volumes of gaseous petroleum. It contains in one litre 0.265 grain of carbon. It is easily prepared of constant composition, and in any desired quantity.

I have still to determine what modification needs to be made in the proportion of hydrogen, that is, of dilute acid employed, with samples of petroleum of different specific gravities. Probably it

will be possible to connect by a simple formula the specific gravity of any sample of light petroleum with the proportion of sulphuric acid which must be used with that sample, in order to furnish sixteen-candle standard gas.

It remains for me to describe briefly the form of photometer which Mr. F. W. Hartley has arranged for me, in which to compare the sample of gas to be tested with the standard gas. It corresponds to the ordinary open photometer, with a sixty-inch bar, except in the following particulars:

Both ends are furnished with similar "London" argand burners, with the usual appliances for measuring and regulating the current of gas, all in duplicate. By a suitable arrangement of cocks either sample of gas may be sent into either meter, and thus to either burner. The center line of the bar is numbered sixteen, and two scales having this line in common are drawn out, one beneath the other, so that the position of the pointer which travels with the disc can be read upon each.

One scale is to be used when the standard gas is burning on the right, and indicates the value in candles of the gas compared with it; the second scale is the reversed image of the first (corresponding to it as the image of an object in a mirror does to the object), and is to be used when the standard gas is burning on the left. When a reading has been made on one scale, the samples of gas are to be reversed and a second reading made on the other scale. The geometric mean of these two readings is the true illuminating power of the sample of gas tested, depending for its accuracy upon the quality of the standard gas, but independent of variations of temperature and pressure, and of all inequalities in burners, meters, or disc.

Comparing thus directly one gas with another it is likely that the nature of the burners employed will make little, if any difference, at least where the gas tested has nearly the same illuminating power as the standard gas. If so, an indirect but important advantage that would accrue from the adoption of this method is, that a question which has been hotly debated, as to what kind of burners ought to be employed in testing the illuminating power of gas, would disappear altogether.

STUCCO.

From "The Builder."

We have it on very good authority that the British public in one of its periodical fits of morality is a ridiculous spectacle. That small portion of it which sacrifices at the shrine of Culture, as the priest of that goddess have depicted her,—that small portion which settles the fashion in things artistic,—betrays perhaps the biggest indignation in its chronic stand against the untruthfulness of much that contributes to mnndane happiness, and springs from mundane success. The man who whitewashed the painted walls of too many a church and cathedral while the plague was playing high jinks in the metropolis, has probably had an opportunity of explaining to his companions in Hades how he did it with the best intentions, and the reports of the most recent *convoi* of churchwardens have probably confirmed him in the ignorant assumption that what he attempted for sanitary reasons has been since successfully accomplished for artistic ones. But, happily, that man, as far as British humanity goes, is as extinct as the dodo, and as little likely to reappear by any sort of reversion as that remote ancestor from whom he and his posterity are said to be descended. The small portion of the community to whom the country is indebted for a just appreciation of æsthetic sensation not only stands in his way, but guards every approach to the maze of modern architecture—to the center of which no key but Truth is now enabled to penetrate. For of what value is an æsthetic

sensation if it be not thoroughly genuine? A Pilate might ask jestingly—What is Truth? and be careless of the answer; but more modern judges live in such an atmosphere of artificiality that they are bound, not only to put the question with the strictest sobriety, but also to answer it themselves according to the sternest definition. It is quite useless to urge upon them the dictum of a great French exponent of imitation in the fine arts—quite superfluous to urge with him that, in every art there must be some fiction with respect to truth and something incomplete with respect to resemblance. They take the letter of the law, which they translate in accordance with the terms of a particular vocabulary—all other translators and vocabularies being hopelessly at fault. Although for long years the world has been led to believe that the art of concealing art was approved by gods and men, the cultivated Mrs. Grundy (the goddess Ydgrun of Erewhon) objects to any sort of concealment whatsoever. She has not only fished up from the bottom of a well, Truth, that had modestly sought refuge there, but persists in exposing the unsophisticated fugitive to the public gaze; and were the latter ungenerous enough to retaliate, there would soon be an end of the "vain opinions, flattering hopes, false valuations, imaginations as one would, and the like," without which, as Bacon said, the minds of men would be "poor shrunken things;" and an end too of all further possibility of making up that "bundle of inconsistencies and contradictions" which, according to Swift, help to compose the life of man from youth to old age. Mrs. Grundy, with Truth in leading-strings, would make the Lares and Penates of modern communities almost Japanese in unadorned starkness; and in denouncing the works of the Evil One she has included stucco amongst them. She has not only prayed to be kept honest, but, moreover, to be surrounded during her lifetime with honest brickwork, and her prayer has been heard. The bricklayer, the carpenter, the joiner, in churches, schools, and houses, have since bared their bosoms to the multitude. The sculptor has discarded finish or refinement in order to show mankind that he has been working with a tool; the painter has so dispersed his groups as to allow spectators the gratification of seeing between them the kind of material upon which they are depicted. Oak has been gilded on condition that the grain of the wood could work itself through; or it has been painted whenever the ingredient which renders paint durable and efficacious could be omitted. The pursuit of purity has extended to the head of a nail, the cut of a screw, the adornment of a nut. The rivets of an iron plate were never so hidden or so loftily placed but the architectural purist has displayed for them his loving care; and at the close, when new stone, new brick, and new wood appeared unblushing and innocent, the happy architect has turned round to receive the applause of Mrs. Grundy and her troop of followers; and, like "Truthful James" of Bret Harte's poetical fancy, he has been enabled to say, but in the most ordinary prose, "Ladies and gentlemen, there is no deception."

Then it was discovered why architecture had been an admitted failure since the revival of classical learning reformed the world. It lacked Truth! Modern marble and stone were not marble and stone, but stucco! Then it was resolved that the principles of architecture must no longer be violated with impunity; and, as stucco had audaciously laughed them to scorn, it was necessary for the English artist to teach his less happily inspired countrymen the importance of artistic purity and truth. Stucco, therefore, acknowledged the power of the greatest number and retired into obscurity,—only issuing from it at intervals to improve a fallen neighborhood or renovate an economical palace.

We are not going to break a lance on behalf of stucco and its wrongs; nor could we, even if so disposed, hold a brief for chunam, scagliola, gypsum, or any kind of cement; but the temper of Mrs. Grundy is so far moderated now as to permit a reasonable remonstrance against the prolonged ostracism of a material which gives to the rough nature of bricks something of that softness which manner gives to the rough nature of man. Addison, who, though an incompetent critic of the former, was a good judge of the latter, said: "The very design of dress, good breeding,

outward ornaments and ceremony were to lift up human nature and set it off to an advantage." If the "noble savage" scorned a lie, he also objected to many of those modern observances the disregard of which banishes some men from society and involves others in a temporary loss of liberty. Swift was probaly only half-laughing at the world when he told it that "Good manners is the art of making those people easy with whom we converse," and surely to do that requires the effort sometimes of no small an amount of tact, if not of deception. The reproach of the Frenchwoman to an indignant lover, that people thought the things he said, but never said them, is perfectly consistent even with the highest morality. Although speech may *not* have been given to man to conceal his thoughts, it is certain that with speech he conceals them; and so admirable sometimes is modern training, that even an ingenuous countenance can be feigned; whereas, as Queen Isabella of Spain, in Bacon's time, used to say, "Whosoever hath a good presence and a good fashion carries continual letters of recommendation." Surely this good presence and this good fashion are but a covering to that material of which all men are composed,—a stucco, which, like that on "honest" brickwork, makes it smooth to the eye and soft to the touch. It is a covering also which admits of all sorts of adornment, both in the one and in the other; for what wit can effect for human, color can effect for material, polish. You are no more justified in banishing stucco from your walls, because on some of them it has been falsely applied, than to condemn suavity of manner because it has often favored the artifices of a knave.

It is very much to be doubted whether the ancients, having built a rough stone wall, ever refrained from improving its appearance by covering it with a coat of stucco lest the critics should accuse them of lying. On the contrary, they often made with rough stone and brick, covered with a coat of some kind of plaster, beautiful works of art; and such, according to Quatremère de Quincy, "have rather given birth to theories than theories to beautiful works." The Greek plaster, however, must have been a very superior description of covering; for from the walls of Grecian houses, according to Vitruvius, the decorated covering was often detached and carried by rich Romans to Italy to be incrusted in the walls of their town and country mansions. It is well known that at Herculaneum were discovered squares of plaster adorned with paintings, which had evidently been detached from some other place, and which the workmen had not had time to incrust in the walls of the house where they were found. The ruins of antique edifices in Rome, such as the Baths of Caracalla, of Titus, and of Diocletian, have shown a thickness of stucco of from four to five inches. Mr. Newton, in the course of his explorations at Halicarnassus, discovered some fine specimens of stucco made of lime and pounded marble with ornaments painted on them; and at Rhodes he found similar fragments, which still retained their painted ornaments after long exposure to weather and rough treatment. Indeed, it is quite superfluous to attempt proving that the use of stucco is as old as architecture. Sometimes sundried bricks in early Egyptian monuments were coated and painted just as the walls of coarse tufa or travertine in the beautiful city of Rhodes were coated and painted, and as our modern walls are treated, though these with less valuable material and a less artistic mode of decoration. Colored marbles were imitated in stucco by the ancients; and, in the Middle Ages, red lines were traced upon it to imitate, in perhaps a conventional fashion, the jointing of a stone wall. A stucco covering of some sort was spread over both the inside and outside of many ordinary stone buildings erected by the Greeks. On the outside it was comparatively thin, and frequently, if not always, colored. On the ruins of a temple at Agrigentum there are now standing columns composed of several drums of rough stone covered with a thin white stucco of uniform thickness, hard, and beautifully smooth. Similar ruins, similarly stuccoed, are to be seen at Pæstum. In the Temple of Vesta at Tivoli, although the flutes of the column are made in the stone itself, their finished form is obtained by the stucco which covers it. Some Mediæval churches in England were stuccoed on the outside, and parts of the original coat have been

found clinging to them. Many Italian masterpieces, with which the names of celebrated architects are associated, bear on their faces, pilasters and similar ornamental accessories, as defenceless in principle as those on the housefronts of Bloomsbury or Belgravia; and Mr. Ruskin is too honest to evade the fact that some of the "marble palaces" of Venice are faced with stucco; but he says it is "confessed and understood, and laid on the bricks precisely as gesso is laid on canvas in order to form them into a ground for receiving color from the human hand,—color which, if well laid on, might render the brick wall more precious than if it had been built of emeralds." The palace at Madura, the ancient capital of Southern India, is built of stone and brick, plastered, to which fact, according to Mr. Chisholm, is due its present existence. Cairo, which has been the theme of so many rhapsodies about Oriental gorgeousness and beauty, is, as a whole, principally plaster and paint; and the palaces of Chowringhee, which astonished Macaulay as much as our "magnificent Regent Street" delighted him, are stuccoed from basement to roof.

The story, known to all, and frequently quoted by the more youthful, of that singularly acute member of our craft who, after having cut his own name on a stone wall, stamped that of the king, his master, upon the stucco which covered it, is eminently suggestive to moderns, who are often invidiously compared with their brethren of the past. The giants of those days seem all the greater now that every trace of their contemporary pigmies has disappeared. The dignity of history prevented us knowing, until the days of the most delightful of historians, many petty details about the mass of our countrymen, such as, in his own words, "how the parlors and bedchambers of our ancestors looked." It has, therefore, been the fashion to consider that since the "monuments" of antiquity and of the Middle Ages have resisted so long the ravages of time, the workmanship of the ancients and of our ancestors reached a degree of excellence which cannot now be approached. That it was superior no one is audacious enough to deny, but neither can it be disputed that all their bad work has disappeared. Philæ the Beautiful, the Athenian Acropolis, the Coliseum, the ruins of many a French and English castle, were surrounded in the time of their strength by a more or less teeming population contented with shelter of a comparatively perishable nature, which demanded constant attention at the hands of the inhabitants. Neither Phidias nor Praxiteles sought on the hill of Pentelicus the materials of their own abodes. The Athenian citizen was noted for the modesty of his dwelling-house; and far from building a home for posterity, or, as the French workman says, for eternity, he built a rough wall, which he left those who succeeded him to renovate with a new coat of stucco, or revivify with another and perhaps a different story. The modern weakness has long consisted of an attempt to imitate earlier public buildings in our domestic dwellings, with the sole result of bringing down our public monuments to a level with private buildings. The riches of the earth, say, have contributed to render the walls of a town-hall or a church brilliant with all the colors of the rainbow; therefore, unless you can command the former you must not hope to enjoy the latter! You must not hide the materials which compose your wall, according to the purists; you mnst not cover rough stone or coarse brick with plaster, for thereby you produce an effect of homogeneity the possibility of which is precluded by the numberless horizontal and vertical joints of a brick or stone wall. If you want color you can get it out of the bricks themselves, and you may paint upon their surface. Even if the wall be of concrete, purists have objected to a coat of cement without, or a coat of gypsum within. They have always had at their command such missiles as "sham effects," "veneering," "imitation ornament," to fling at those who attempt to reason with them. Mr. Pullan, a short time ago, very naturally thought that to decline to hide the face of honest but ugly red brickwork with a coat of plaster is puerile. "I must confess," said he, "that I think it perfectly justifiable to use either veneer of marble, variegated scagliola, or colored stucco, for the purpose of obtaining color in cases where funds do not allow of the purchase of blocks of marble,"

and he added a hope that before long many of the dismal-looking churches erected in London during the last two centuries might be enlivened with polychrome. Mr. Penrose appears to entertain a similar opinion, for on the same occasion he was glad to hear that the colored bricks often used in the interiors of churches are simply "ground" for future painted decoration! "In themselves," he added, "they appear crude, unfinished, and distracting, though some times used with great cleverness." But he denied that in all cases such a decorated coloring was intended, because, said he: "I have seen several restored churches in which I have grieved over walls left so rough after the removal of the plaster as not even to be suitable for garden fruit walls." Mr. Pullan's calm assertion shared, with the rash impulsiveness of Mr. Penrose, an equal fate. No less a person than the then President of the Institute of Architects fell foul of both. "It may be," he indignantly exclaimed, "that those who have so nobly lifted up their voices against this gangrene of modern architecture have fallen into the opposite error of purism; but surely in these days when every kind of counterfeit adulteration and practical falsehood pervades every branch of business, of art, and of manufacture, ... it is not the time to jeer at those who may possibly overstrain their protests against the practical vices of the age." No one will dispute the justice of Sir Gilbert Scott's remarks or dare to doubt, —even without the fear of Mr. Ruskin before his eyes,—the possible creation of Utopia. The ancient philosophy pretended to make all men virtuous; and virtue as the highest good is preached to all, properly enough, at the present hour. Mr. Disraeli, in one of his novels, has described a young gentleman who set himself the task, on entering Parliament, to abolish poverty,—success, in which, one would think, might have helped to make truth universal. But, on the other hand, riches are known to be the impedimenta of virtue; and there is hardly a comedy of recent times which does not enlarge upon some text taken from the Great Book of Snobs. The purists have dozens of apt quotations at their command. Take only the indignant shopkeeper in the "Maison Neuve," where he upbraids his ambitious nephew and laughs at *salons* which lie from the mouldings of their doors to the ashes of their hearths; which are stucco looking like marble, pasteboard looking like sculpture, pear-tree looking like ebony. And then he points the moral,—"Rub and it comes off, strike and it chips! Hired lackeys, that you call '*mes gens*,' friends that you do not know! . . . . . Familiars chosen, like your furniture, above your means, and, like it, second-hand! Everywhere, morally, physically, varnish, veneer, pasteboarding, and imitation-bronze." Surely, Mr. Penrose and Mr. Pullan, you must have forgotten that this was the stucco of an Empire which began with a *coup d'état* and ended with Sedan! Ought you not to thank our purists for pointing out faults which might drag this home of constitutional liberty and Portland cement through the confusion of a similar fate?

Nevertheless, all the arguments and remonstrances against the use of stucco will not alter the fact that in this country we have comparatively little stone and less marble; and that even if we had a great deal of the latter, the climate is not favorable to its employment either on the outside or the inside of our houses. We have magnificent granites, and know how to polish them better than any other people in the world, but they are far too expensive to be used as mere wall lining; and the most we can hope to do is to make our columns and other important points of support of such materials. But in the modern rage for honesty it often occurs that a brightly-polished granite shaft is placed in close proximity to a rough brick or a rough stone wall. The hesitation to hide this roughness with a smooth coat of plaster arises probably from a logical disinclination to mix up a thing so truthful as polished granite with a thing so false as stucco. Again, having very little stone, we found out how nature went to work to make it, and have succeeded in making a similar substance; but, with this difference, that the one is nature-made and the other art-made, and that while we are obliged to cut the former we must cast the latter in a mould. Suppose then that we go to work with nature's ingredients to make a stone wall—*sur place;* and that we

have built the heart of the wall in Portland cement concrete, can there be any objection to putting a covering upon it similar to the crust which is formed upon natural stone? Portland cement is one of the great facts of the day, and it is ashlar formed by hand upon the wall itself instead of being cut by hand in a workshop and inserted in the wall—with the exception, of course, that Portland cement ashlar is often one-half inch thick, and Portland stone ashlar often three inches thick. Strangely enough, although objection is made to stucco, none is made to mosaic. There are shafts of columns at Pompeii composed of brick covered with small cubes of marble; and these mosaics are nothing more than stucco concealing a core of inferior material. Bricks and terra-cotta blocks are after all only a species of stucco which has been baked and thus made ready for insertion in a wall instead of being run against it; and as the late Mr. J. W. Papworth said in one of his admirable papers, "if moulded terra-cotta is a truthful material, run plaster cornices are also legitimate." But putting the æsthetic part of the question on one side, and forgetting the *pros* and *cons* of it, there can be no doubt that a great deal more plaster and paint, more stucco and mosaic wall-coverings, might be used with advantage in the insides of our houses; and that wainscoting and wood linings,—which the Greeks never used, and which in countries like India, for instance, cannot be used,—harbor vermin and insects; while paper even of the best kind is known to possess, in a sanitary point of view, absolutely dangerous qualities. If uncompromising truth in architecture be carried to its logical conclusion, painting and sculpture, which on a building are its subordinates, must often be positively false; for a painted perspective upon a flat surface, and a bas-relief in marble, are both attempts to deceive. The trunk of a tree should be carved in wood, a musical instrument inlaid with brass, and drapery worked in some kind of stuff. Probably Pope had a glimpse of the future, at least as far as the æsthetic development of "purism" goes, when he wrote:

> "That live-long wig, which Gorgon's self might own,
> Eternal buckle takes in Parian stone."

The pages of this journal are not sufficiently encyclopædic to catalogue the many different sorts of stucco that, for the last two thousand years, have been used to envelop walls composed of materials quite as "honest" as any which, in this era of virtue, are too frequently left naked and unprotected. The MS. of Professor Donaldson's exhaustive treatise upon stucco, printed in the "Encyclopædia Metropolitana," lies open to all in the Library of the Institute of Architects. The *tectorium opus* of the Romans, with which Vitruvius has familiarized his readers, and the *chunam* of the Hindus, are probably of equal antiquity. At the present moment the preparation and application of the latter is best understood in the Madras Presidency. The plaster coats, on ancient Greek and Roman walls, consisted generally of three layers of mortar composed of lime and sand, and three others of stucco, composed of powdered marble and lime—the powder of marble being finer as each layer was applied until in the third it was exceedingly fine. Chunam is of two kinds; that used in parts of the interior of India being prepared from a gravelly kind of limestone, dug out of quarries, while that used along the coast is made from shells washed out of the salt marshes; and the latter is thought to be the more durable of the two. But the excellence of both depends undoubtedly on the mode of preparation and manipulation. The columns in the interior of Government House at Calcutta are coated with the very finest description of stucco, and it is affirmed that the materials (excepting, perhaps, the quartz sand) for making good shell-chunam are better in that part of India than in Madras, only in the latter Presidency the "elbow-grease" is more effectually applied. This shell-chunam is a fine, impalpable powder, while the stone-chunam is a coarse, sandy one. Both one and the other are mixed with clean, sharp sand, in various proportions, according to the use for which they are intended. Mr. Chisholm has explained the process for which Madras is famous. He says:—"The first coat generally consists of three parts of river sand to two parts of shell-lime laid on roughly by trowel and hand-float. The second coat is composed of ground quartz, sand, and shell-lime in equal proportions, brought to a surface

by Derby floats in the ordinary European manner. The third coat is a similar mixture, ground very fine to the consistency of cream. This is troweled on, and polished with agates. After applying the creamy mixture, the workman continually rubs the surface with the agate held in the right hand, while with the left he occasionally dusts the surface with fine, dry, powdered quartz, contained in a small linen bag." If any one be imprudent enough to doubt the force of "elbow-grease," not only in the matter of good stucco, but of all materials with a "face," let him watch in Eastern India, native workmen polishing an oak floor with empty beer-bottles. The modern tendency, however, in this country, is not to obtain smooth or polished surfaces so much as to destroy dead ones, and this deadness is songht to be removed by stamping patterns upon it. We take it, on the contrary, that our English climate in general, and our London atmosphere in particular, demand the means of throwing off, rather than of harboring, dust and damp, which, once combined, form dirt.

We said at the beginning that we held no brief for any kind of stucco; but if we have taken up its defence with a will, and have by any chance proved stucco to be right, we have proved ourselves wrong; for, undoubtedly, as the great mass of people have used it, do use it, and will continue to use it, it is irretrievably wrong. Witness the article in the "Penny Cyclopædia" of the year 1842, and compare the custom of to-day after thirty-four years of culture to boot: —"Much will depend upon the skill and care with which stuccoing is executed, on its being made to resemble stone as closely as possible both as to tint and the grain or surface; and in order to render the deception as complete as possible, it is important, though it is not always done, that lines should be made on the face of the wall indicating joints and courses of stonework. If perfectly well executed, stucco will be nearly equal in appearance to stone, and even superior to that of stone of inferior quality. There are some who protest against the use of stucco altogether, as a spurious and meretricious mode of building with sham material, but . . . it has been favorable to architectural design, and promoted a taste for it by allowing it to be executed when stone would be too expensive a material, or where, if stone were employed, the same extent and degree of enrichment could not be afforded." Happily there are not wanting thousands amongst the millions who inhabit these islands to understand the utter falseness of such an argument and the gross injustice thereby done to an excellent building material; and having such a warning before our eyes, some captious reader may well ask, why we wrote about stucco at all? Why not let sleeping dogs lie? Why stir mud any more than pitch?—for though stucco is neither mud nor pitch, the slime of the Tiber has helped to make one kind, and the slime of the Dead Sea another. Those, however, who love stucco will probably admit the excellence of any argument we may have used in favor of it, and those who hate it may recall a witty anecdote. When some good-natured friend told Stella how beautifully Swift had written regarding her rival she expressed no surprise, for she knew the Dean had also written finely about a broomstick. Many worthy people have, doubtless, long thought about stucco in a spirit similar to that which urged the satirist to treat of a broomstick; and so, perhaps, it is necessary now and then to say a word to such—not finely, but in a homely fashion—concerning an ancient material which in proper hands may be made just as artistic and lovely as it is comfortable and clean.

CINCINNATI MUSIC HALL.—The work of demolishing the old Cincinnati Exposition buildings is now going on. The erection of permanent buildings for a music hall and for future expositions is to begin soon. It is expected that the new building will be ready for the biennial musical festival next May.

ERRATA.—In the illustration on page 169 of our August number, there are represented but four slits for the admission of gas, whereas there should be six, one for each sector.

Also, on page 171, in second column, the statement regarding the number and size of the sleeves should read: "90 sleeves; 62, 9″ long, and 28, 12″ long."

THE MONCRIEFF GUN CARRIAGE.

From "Iron."

SINCE that remote date when Esau's savory feast was forestalled by the imitation served up by his brother, there has been no end to the grievances of inventors. The man who originates anything must prepare to act, to "be done," and undoubtedly to suffer. He must endure the incredulity and distrust of friends, the open hostility of rivals, and, if his invention be of national importance, the stony indifference of officials. It is, perhaps, hardly to be wondered at that the routine and experience of a public department should induce a feeling of scepticism tempered by despondency. There are so many inventors ready—too ready—and too desperately willing to increase the efficiency of every department, and save a large sum of money at the same time, that Government officials naturally become hardened by practice. They know every kind of inventor—the bland, persuasive man who cannot be shaken off—the rough-and-ready customer who will not be said nay to—the combative "genius" who rushes into print and ventilates his grievances through the medium of the press. They have, or imagine they have, a perfect system for getting rid of these people, by reducing them by degrees to utter weariness and heartsickness. It is, to the patient student of human nature, by no means uninteresting to watch the change brought about in a once sanguine inventor by the contact of officialism. At the beginning he is bright and buoyant. He has obtained, or rather thinks he has obtained, the ear of persons in authority. His invention has been talked over, and a committee to report on it talked about. Probably the affair never reaches the actual committee stage at all—but, admitting a committee of experts to be actually appointed, the troubles of the inventor have only commenced. He bears up bravely for a while, but committees and reports prove too much for him in the long run. Unless gifted with both health and wealth he finds himself shrinking painfully both in purse and in person. Years and anxiety plant a plentiful crop of gray hairs over the inventive brain, but yet no advance is made. At last, in the fullness of time, the invention is reported upon favorably, and, if the inventor have not gone mad or died in the meantime, he is allowed to work his wicked will upon an old ship or a batch of rusty guns.

Such is the ordinary lot of those who seek to increase the naval and military power of England and enrich themselves at the same time, but occasionally a fortunate individual enjoys rapid, if incomplete, success. Major Moncrieff, whose gun-carriage is familiar to our readers, is a case in point. Up to a certain stage his relations with the powers that be were eminently satisfactorily, but, at the moment when he expected that his views were about to be adopted in their entirety, he found that—thanks to some oversight or misconception of his plan on the part of the committee appointed to report on it—the Moncrieff system was to be laid aside for the present, or, if not entirely abandoned, entrusted to other hands. In order to arrive at a perfectly clear apprehension of the position claimed by Major Moncrieff, it is in the first place necessary to get rid of the impression that the elevating gun-carriage is the be-all and end-all of his invention. Practically, the adoption of his plan would revolutionize the present system of fortification ; and if the application of hydraulic carriages to guns of heavy calibre proved successful, fortified embrasures and casemates would be things of the past. As the gun, mounted on Major Moncrieff's principle, rises from the bottom of a pit, delivers its fire, and then sinks into security, the heavy ordnance placed on coast fortifications would be protected by a continuous parapet which could hardly be breached. To the advancing enemy no gun would be visible till the instant before it was discharged, when, rising on its elevating platform over the edge of the parapet, each piece would possess the advantage of a gun *en barbette*. No artillerist is blind to the advantage of guns placed on this plan, the only drawback hitherto having been the danger incurred—owing

to the improved construction of shrapnel—so great that no engineer would attempt to oppose guns *en barbette* to a heavy fire of sea-shrapnel. It is claimed, and with considerable justice, for Major Moncrieff's system, that it combines the strength of a continuous parapet, the wide range, and consequent efficiency of guns *en barbette*, and an equal measure of safety with the shield system on which so much money has been expended. It is also pretty clear that one gun *en barbette*, can do the work of two in embrasures, and that therefore the proposed fortifications of the future have on their side the merit either of increased efficiency or of greater economy, at the option of the constructor. To this complexion has the Moncrieff system been brought in the fulness of its development—a process extending over nearly a quarter of a century. So long ago as 1858 Major Moncrieff brought his plan under the notice of the Government. In 1865 when, owing to the improvement in artillery, the necessity for increased protection to batteries was acknowledged, the iron shield system came into notice, and proved a sturdy opponent to the elevating carriage. Nevertheless, the latter made its way by degrees, and advanced in the favor of experts, until the period when the increased size of guns rendered, in the opinion of Major Moncrieff himself, the substitution of hydraulic power for the original counterweight principle absolutely necessary. In his own opinion, as expressed on various occasions, the counterweight principle was not adapted to guns exceeding 18 tons—applied to a 12-ton gun it worked admirably, but when one of 18 tons was to be dealt with the hydraulic, or hydraulic-pneumatic system, was preferable. This view was so very distinctly put forward by Major Moncrieff in a written statement to the present Secretary of State for War that it is almost inconceivable that any misunderstanding could occur. That such misunderstanding did occur, however, is now a matter of history.

In the statement referred to—dated 28th of April, 1874—the inventor confined himself to the definite point of recommending the immediate manufacture of a Moncrieff carriage, worked by hydraulics, for an 18-ton gun, and gave in a succinct form his reasons for taking that course. This statement was referred by the War Minister, through the Director of Artillery (Sir John Adye), to the "Committee on Moncrieff Carriages" for their report. To that committee Major Moncrieff was refused access, and was not even allowed to show the committee a model in illustration of the statement on which they were requested to report. It would appear, also, that the committee had at no time very distinctly before them the proposition of Major Moncrieff, and were left in doubt whether he advised the construction of an 18-ton gun-carriage on the counterweight principle, or, as was really the case, he preferred the manufacture of an hydraulic carriage. In going through their report on the statement laid before them it is difficult to resist the conclusion that, whatever may be the value of the Moncrieff "hydraulic" system, its supposed merits were by no means properly set before the committee. The concluding paragraph of their report records that they "did not understand clearly" whether the construction of an 18-ton gun on the counterweight or on the hydro-pneumatic system was asked for; and simply concurs with the inventor in deprecating the extension of the counterweight principle to heavy ordnance. The almost immediate dissolution of the committee deprived Major Moncrieff of all opportunity of explaining the misunderstanding under which their report was apparently framed, and it would seem that the subsequent efforts of that gentleman to obtain a hearing from the War Department met with but little success. Without entering into the vexed question of the comparative merits of the "shield" and Moncrieff systems, and the costliness of the latter if extended to heavy guns on the counterweight principle, we may yet express our regret that an eminent inventor, whose efforts up to a certain point had received official as well as popular sanction, should have been unceremoniously laid on the shelf. Of two things one. Either Major Moncrieff's *hydraulic* system is costly, unpractical, or for some other reason inapplicable to heavy guns, or it possesses the advantages claimed for it by the inventor. In either case his success in the counterweight system—so far as it went—ought

to plead in his favor for a calm and patient investigation of the latest development of his idea.

REPORTS OF ENGINEERING SOCIETIES.

INSTITUTION OF MECHANICAL ENGINEERS.—The summer meeting of the members of this Institution was held recently in Birmingham—Mr. Thomas Hawksley, president, presided.

Mr. W. P. Marshall, secretary, read a paper, prepared by Mr. William E. Rich (London), on "Dynamometers, Friction Brakes, and other Testing Apparatus belonging to the Royal Agricultural Society of England." The paper referred at great length to the three more important instruments belonging to the society, which were classed under three heads—1. Traction dynamometers, for measuring the draughts of implements and vehicles drawn by horses or otherwise.—2. Friction brakes, for absorbing the power developed by steam-engines and other prime movers by uniform frictional resistances.—3. What were commonly called rotary dynamometers, which registered the amounts of power that must be transmitted to various machines from external sources in order to work them.—A vote of thanks was passed to Mr. Rich for his paper, and a brief discussion followed.

The Secretary next read a paper "On Mechanical Puddling," by Mr. T. Russell Crampton, London. The author said that the operation required considerable intelligence and excessive labor, and it was the successful combination of those two elements which constituted the great difficulty, as evidenced by the high wages that good puddlers could command. Although the requirements for good puddling were apparently so simple, manual labor was not to be depended upon for that purpose, consequently mechanical puddling had been called into requisition. Sufficient had been established to enforce the conviction that puddling by the revolving chamber was superior as compared with hand puddling or other rabbling, as not only were the yields increased, but the quality of the product was most strikingly improved. The most careful efforts had been made to obtain equal results by hand from like material, but in every case the rotary puddled product was the best. A number of drawings were suspended in the theatre for the purpose of giving a general idea of the various arrangements proposed. It was stated by the author that in his furnace, where the firing was done mechanically, little skill and no exhaustive labor were required. In order to show the effects of the two systems of making iron there were laid on the table a series of samples, consisting of plates and rails, some produced by the best known makers by the usual process of building up small pieces, and others made from one homogeneous puddle ball.—A vote of thanks was passed to Mr. Crampton, and the meeting adjourned.

The meeting was resumed next morning, with a further discussion on Mr. Crampton's paper "On Mechanical Puddling." Mr. W. P. Marshall, secretary, read a paper prepared by Mr. Francis Preston, of Huddersfield, "On McCarter's Condenser without Air-pump for Steam-Engines." The writer stated that many attempts, with varied success, had been made to introduce a condenser without an air-pump, but he believed there had been no successful application of a condenser without the aid of an air-pump, and capable of lifting its own injection water, previous to the one which formed the subject of the present paper. The construction and working were then explained by a number of diagrams. The condensers had been successfully at work upwards of three years, in conjunction with engines from 12 in. cylinders to 37-inch cylinders, giving every satisfaction, effecting a considerable saving in coal, besides giving much steadier motion to the machinery, caused by the regularity of the working of the condensers, without the great strain being put upon the engine through the ordinary air-pump at every revolution of the engine. Illustrations were next given of the successful applications of the condensers. In one instance it was stated that the engines had done more work in the mill than in any other month, with a regular speed and with greater ease, besides saving fuel in money value amounting to 33 per cent. The paper concluded with reference to a recent calculation made by Mr. James Wood, engineer, of Burnley, in which a comparison was made as to the relative volumes of steam expended in the working of an ordinary air-pump and the McCarter condenser, in an engine at Messrs. Crossley and Son's Albion Mills, Halifax. Mr. Wood's report showed that there was a difference of 1,161 lbs. degrees of heat in favor of the condenser, or equal to 25 per cent., a percentage which must not be considered as showing the whole economical advantage which existed over the ordinary air-pump.

After a brief discussion, a paper, by Mr. Bernard P. Walker, of Birmingham, was read "On the Frisbie Fire-Feeder and Grate for Boilers and Furnaces." The object of this apparatus is to supply the fuel at the lower surface of the boiler and furnace fires, instead of at the upper surface. It was stated that the system of firing by inserting the fuel from beneath presented the following advantages:—1. The fire was not reduced in intensity by the cold fuel damping the flame when thrown on the upper surface of the fire, so that the evolution of smoke from this cause was completely avoided.—2. Each successive charge of fuel lifted up and most effectually poked the fire.—3. The cooling of the furnace by the admission of a large volume of cold air when the fire doors were opened for stoking was avoided.—4. A smokeless flame was readily attainable with a thick fire, although using smaller fuel than could be employed in ordinary furnaces, with a maximum intensity of heat. One of the furnaces had been in constant work for nearly four years at Spring Hill Rolling Mills, Birmingham, where it had been proved thoroughly satisfactory. Mr. Walker, in conclusion, stated that from 20 per cent. in steam-engine boilers to 60 per cent. saving in cost of fuel in reverberating furnaces used for smelting nickel, had been effected by its use.—*Mining Journal.*

IRON AND STEEL NOTES.

"MILD" STEEL.—With the advance of science old definitions become obsolete; and terms which conveyed a certain idea to our grandfathers, or even our fathers, demand some qualifying epithet in adapting them to the terminology of our own times. The individual who was puzzled at the information that "pigs," after having been heavy, were now rather livelier, would be no less astonished at the association of the adjective "mild" with that metal which of all others he was accustomed to associate with war, strife and murder. Nor is it the case, unfortunately, that it becomes necessary to qualify the noun *steel* with the adjective *mild*, on the application of this metal to peaceful purposes alone; for one of the chief uses to which "mild" steel is put, is to form the skin of vessels of war. It has been said that, to constitute steel, the metal should be capable of being welded, tempered and hardened. But this definition, though general enough to include all the different varieties of this metal, made by the various processes, that are capable of these operations in different degrees, is not sufficiently exact to distinguish any one of them without some qualifying adjective, such as that at the head of this article for instance. "Converted metal" seems too cumbrous a term for our high pressure age; so, perhaps, the names of the inventors of the various processes will assist us. We speak of the Uchatius process and of Bessemer metal; why not employ the term Siemens-metal to distinguish the homogeneous product of the united Siemens and Martin processes now so generally employed on the Continent, and also coming gradually into vogue in this country?

In the first series of Cantor Lectures before the Society of Arts, Mr. Mattieu Williams described, among others, the Siemens-Martin process, saying that it afforded a homogeneous "mild" or "semi" steel with varying but definite proportion of carbon, somewhat harder than wrought iron, but with nearly all its toughness, and capable of being wrought almost as readily as iron. Those who were present could not fail to have been struck by the remarkable specimens of this metal, bent while cold into all sorts of fantastic shapes, having been lent by the Landore-Siemens Steel Company.

The works of this company are situated at Landore, near Swansea, having been considerably enlarged by the erection of the "New Works" a few years ago, so that they are now equal to a production of 1,500 tons a week, no less than 1,200 men being employed in the works alone, not including the six collieries, within a short distance, owned by the company. Intersected by the river Tawé and the Swansea Valley Railway, and in close proximity to the South Wales line, these works possess unusual facilities for the reception of the rich hematite ores of Furness and West Cumberland, the spathose and brown hematite ores from the Company's own mine near Bilbao, and the crystalline limestone for flux from the Mumbles, only a few miles distant.

There are two blast-furnaces, fifty-four feet and sixty-six feet high, erected under a hill at the New Works, a position eminently favorable for receiving the raw material, which is run in trucks direct to the furnace mouth, a steam-lift of only a few feet being necessary in one case. The ordinary pig-iron, and also the spiegeleisen for imparting to the metal a proper proportion of carbon, are made in the two blast furnaces, a smaller furnace being occasionally employed for the latter purpose. The blast-furnaces are close-topped, the bells being provided with Head, Wrightson and Co.'s patent hydraulic brakes for lowering the charge. The blast is heated in three of Cowper's patent stoves to a temperature of about 1,400 deg. Fah.; and the pressure at the furnace is about four and a half pounds per square inch. The boilers for raising steam for the blowing engines and for driving the machinery in the melting department are fired by the waste gases. The coke is made in 100 coke ovens quite near the furnace mouth, the batches being drawn by means of an endless chain and steam power. Penrose and Richard's system has lately been tried with the most satisfactory result, a saving of thirty per cent. in fuel having been effected. This process consists in mixing and grinding together sixty-five per cent. of anthracite, thirty per cent. of bituminous coal and five per cent. of pitch from gas-works; and is more fully described in a paper read by Mr. Hackney (a former manager of the works) before the Iron and Steel Institute, at Manchester, last year.

The melting house was erected immediately in front of the blast-furnaces with the intention of running the metal direct into the melting furnaces; but this arrangement has never been carried out, and the usual pigs are formed in the sand. They are conveyed in trucks to the melting furnaces, which are capable of a weekly production of over 1,000 tons of ingots. A ladle, mounted in a truck, is run on rails over the ingot moulds, arranged in a straight line, and fills each in turn, while overhead traveling cranes remove the ingots, shift the moulds, and also serve to draw out the ladles from the furnaces after receiving their charge. The loam lining of the ladles is dried by gas from the producers, applied by means of a movable joint. Both the scrap and ore methods are employed; but no phosphorous must be present in the materials, and the sulphur must not exceed 0.05 per cent. The gas for the furnaces is generated in twenty-four Siemens' producers, collected in large cooling tubes, and led under the floor to the furnaces, where it is directed by the reversing valve into each chamber alternately, the currents being changed every half hour. The charge generally consists of six tons of pig-iron, twenty-five cwt. of steel scrap, and from twenty to twenty-five cwt. of Mokta ore for decarburization, while the proportion of spiegeleisen added depends upon the nature of the product required. On an average, four hours are taken up in melting the charge, when the ore is added in small quantities until the carbon is sufficiently reduced; the spiegel is then charged in, more frequently cold, but sometimes having been previously heated to

redness in an ordinary heating furnace. From seven to eight hours are required for working the charge after it is melted, when samples are taken out and broken for the purpose of ascertaining whether the carbon is sufficiently reduced. The furnaces are built entirely of silica bricks, made at the works from rock obtained in the neighborhood, and the bottom consists of good silica sand, carefully examined after each pour, and refettled when necessary. There are eight more of these furnaces at the Old Works, including two, recently erected, which are capable of melting over twelve tons at a pour. In these furnaces an improvement has been introduced into the casting pit. Instead of the metal being allowed to run from the furnace into the ladle, and then into the moulds, the ladle runs on rails in a straight line in front of the furnace, while underneath there is a circular frame carrying the moulds, which revolves like a turntable, and brings each mould successively under the ladle.

There are four Siemens reheating furnaces for ingots, and two heating furnaces for forgings at the Old Works, as well as two eight-ton and one two-ton hammers, made by Messrs. Thwaites and Carbutt. The mill is provided with two twenty-four-inch roll-trains, one for rails and bars, and the other for plates, driven by a pair of Ramsbottom engines. There are altogether twenty-one Siemens furnaces in the mill department at the New Works (the gas for which is supplied by fifteen blocks of producers), and four eight-ton and one four-ton double-acting hammers by Thwaites and Carbutt. The mill consists of rail train, bar and wire train, and a patent tire mill, worked by hydraulic power, designed by Mr. Webb, of Crewe, and made by Messrs. Craven Brothers, Manchester. The rail train, driven by a Ramsbottom's engine, has two pairs of twenty-four inch rolls; and the rail is conveyed on revolving rollers from the last pass to the saw, made by Kitsons of Leeds, which is hung in a swing frame and advances to the rail, while a self-acting clutch holds the rail fast.

A forty-ton lever testing machine by Bucktons, of Leeds, has lately been erected at the Old Works for the purpose of carrying out the Admiralty tests for the "mild steel" plates now being supplied by the company for H.M. despatch vessels *Iris* and *Mercury* now being constructed at Pembroke Dockyard. A single balanced lever, in the proportion of twenty to one, gives a pressure, or tensile strain, as required, of a ton on the test-piece for every hundred weight applied at the other end, there being a pressure ram at one side the main fulcrum and shackles for tension grips at the other. As at the testing-house at the Barrow Steel Works, there is here, also, a remarkable collection of bars of all sections twisted up, and even tied into knots cold, thus showing the remarkable homogeneity and toughness of the metal.

Dr. Siemens, D.C.L., F.R.S., &c., is the chairman of the Company; Mr. J. Riley, the manager of the works; Mr. Arthur Willis, F.C.S., son of the late Prof. Willis, the head of the laboratory; and Messrs. Campbell and Morris, general agents. Latterly, we understand, a considerable impetus has been given to the manufacture of the soft steel for various special purposes, for which the company has now acquired a considerable reputation.

RAILWAY NOTES.

COMPOUND CYLINDER LOCOMOTIVE. — *Engineering* says: "A compound cylinder locomotive is at trial on a French railway. It is the first of a set of similar engines, made for the Bayonne-Biarritz Railway Company by MM. Schneider & Co., Creusot, on the improved compound principle patented by a Swiss engineer, Mr. A. Mallet. These engines have only two cylinders, the small of 9½ in. and the large one 16 in. in diameter; stroke 17⅝ in.; normal gauge; boiler pressure 150 lbs.; weight in working order, about 20 tons. In ordinary circumstances the steam is admitted only in the small cylinder, and expands in the other; but when starting or when a much larger amount of power is required, as on a steep gradient, each cylinder works with separate admission and exhaust. Besides the saving of fuel expected, the capital object is the reduction of heating surface; in the above mentioned engine that surface being only 516 square feet."

SPEED OF TRAINS.—The following are the highest authentic instances of high railway speed with which we are acquainted: Brunel, with the Courier class of locomotive, ran thirteen miles in ten minutes, equal to seventy-eight miles an hour. Mr. Patrick Stirling, of the Great Northern, took, two years back, sixteen carriages fifteen miles in twelve minutes, equal to seventy-five miles an hour. The Great Britain, Lord of the Isles, and Iron Duke, broad-gauge engines on the Great Western Railway, have each run with four or five carriages from Paddington to Didcot in forty-seven and a half minutes; equal to sixty-six miles an hour, or an extreme running speed of seventy-two miles an hour; the new Midland coupled express engines running in the usual course have been timed sixty-eight, seventy, and seventy-two miles an hour. The ten a. m. express on the Great Northern, from Leeds, we have ourselves timed, and found to be running mile after mile at the rate of a mile in fifty-two seconds, or at 69.2 miles an hour. The engines used are Mr. Stirling's outside cylinder bogie express engines, the load being ten carriages.—*Engineer.*

RAILWAYS IN CHINA.—Our readers are aware, says the *London and China Telegraph*, that a company has been formed in London for the purpose of introducing railways into China, and that the first experimental line will be between Shanghai and Woosung, a distance of nine and a half miles. We are now enabled to state that a contract has been entered into between the Woosung Road Company (Limited) and Mr. John Dixon, of London, for the construction of the line, and that the materials for the permanent way have already left for Shanghai. The engineer of the company went out some time since, and will

be on the spot to commence operations as soon as these shipments arrive. It is expected that the line will be completed and in full working by next July, when the novelty of seeing railway trains actually running over the distance in a few minutes may be considered certain to attract a large amount of Chinese passenger traffic. The line being avowedly experimental, is constructed on the narrow gauge of two feet six inches; the funds at command would not admit of anything more. It is no doubt the case that this will be found inadequate to the requirements of a large traffic; but the first thing to be done is to prove railways in China a success, and if the enterprise of the company is able to make this small line a paying concern, there can be little doubt that funds will be forthcoming in this country to provide railway communication between the more important centers of commerce in China; when future extensions of the system can be equipped with every requisite to carry the largest traffic in passengers and merchandise that it would be reasonable to expect for years to come. We believe the promoters of this enterprise will effect more real good in our relations with China and the Chinese than all the treaties and conventions we can obtain.

RAILROAD ACROSS THE EASTERN CONTINENT.—The *Iron and Metal Review* says: The great feat accomplished by the U. S. in connecting the Atlantic and Pacific Oceans by a railroad across the United States is stimulating enterprise in Europe, and it is now proposed—indeed, the plan is matured—to connect the Atlantic and Pacific oceans by a railroad through Central Asia. At a conference of geographers, recently held, Col. Bagdan owitz explained some of the details of the road, which, it is expected, will overcome one of the greatest obstacles to the extension of civilization—namely, the separation of a large part of Asia from Europe by vast deserts, in which no means of transit but a railroad could be of any use. A railroad alone can develop the resources through which it would pass. The mineral wealth of Siberia and the Ural mountains is well known. The exploration and mining of their region would be encouraged and their resources developed. It is proposed that the road shall start from Nijnii Novgorod, in Russia, where now is the extreme eastern station in the network of European railroads. It will run along the Volga, the Kama to Ekaterinburg, on the Asiatic side of the Ural mountains; then enter Asia, proceed in the direction of Truemen and Gmsk, at the Irtish across the river, proceed by the way of Kainsk to Tomsk on the Tem, a branch of the Obi, and across the river. Tomsk is the principal center of commerce of Western Siberia; thence the road will run directly to Irkutsk, at Lake Baikal; thence the road is to pass to the frontier of China, and thence it is no longer an exclusively Russian but an international undertaking.

The first section, from Nijnii Novgorod to Tomsk, runs on perfectly level ground (the so-called steppes), similar to our prairies. In the second section, from Tomsk, to Lake Baikal, the country is rolling and interspersed with rivers and streams; but the greatest height is only 3,500 feet, and the largest rivers are but very moderate in width and depth. The only serious difficulties, as we have said, lie at the Chinese frontier, and they are inferior to those overcome in the Rocky Mountains and the Sierra Nevada by the American engineers. Russia has raised in fifteen years more than $1,000,000,000 with which to construct 15,000 miles of railroad, and can easily find $300,000,000 or $400,000,000 to construct a line of such value to all the civilized world.

ENGINEERING STRUCTURES.

THE BROOKLYN BRIDGE—STRETCHING THE CABLES.—The following is condensed from an explanation made by Mr. E. F. Farrington, Master Mechanic of the bridge construction: There are four piers, two upon each side of the river. On the New York side, the first is an anchorage pier, to which the cables of the substructure, passing over the tower pier, are to be anchored. It is about eighty feet high, and covers six city lots. The tower, standing at the river's edge, 930 feet from the first pier, is 271 feet above high water mark. The Brooklyn tower is the same height, and the span is very nearly 1,600 feet. The Brooklyn anchorage is a duplicate of the New York one. The cables are composed of steel wires, laid side by side and wrapped with a single spiral wire. One after another is stretched from pier to pier, until there are enough, and then they are wrapped, forming a completely rounded cable, containing 6,270 straight parallel wires. There are four cables, making the number forming the main support 25,080 wires. The first rope stretched is made of twisted chrome steel wires, three-fourth inch in diameter, called a "traveler." It has been wound upon a wooden drum which revolves in a frame. The frame will be placed upon a scow at the foot of the Brooklyn tower, and one end of the "traveler" taken up over the tower, carried to the anchorage pier and made fast. The scow will then start for the New York side, paying out the rope and letting it sink to the bottom of the river. When the scow has reached the New York side the end upon the reel will be detached, carried over the top of the New York tower, and brought to the engine house between the two piers, where the hoisting engine is located. It will be fasted to a large drum, which will be turned by the engine. At a moment when no vessels are passing the rope will be raised from the river bed until it is stretched from the anchor pier on the Brooklyn side to the engine house on the New York side. The end will then be carried to the anchor pier and fastened temporarily. A second rope will be brought over in the same manner. The ends of the two will be "spliced" together, and, passing around grooved wheels at each anchorage, forming an endless rope, by which other ropes will be pulled back and forth. A second traveler will then be constructed. These will first be used to carry over seven other principal ropes, viz.: one "foot bridge," four "cradle" and two

"carrier" ropes. The "foot bridge" and "cradle" ropes will be respectively 2⅝ and 2⅜ inches in diameter. The "carrier" ropes will be 1¼ and 1¾ inches in diameter, and put across first, to support the heavier ropes as they are hauled over by the "traveler." Upon the cradle ropes and a foot-bridge rope the foot-bridge is to be constructed, from anchor-pier to anchor-pier, over the tops of the towers. It will be 3½ feet wide, and made of oak slats 1½×3 inches, fastened at each end to longitudinal strips of fifteen feet in length, resting upon the ropes, fastened to the same material. It will be in sections from twelve to fifteen feet in length, resting upon the ropes, fastened by strong iron clamps and guarded by handrails. The cradles are wooden platforms forty-eight feet long by four wide, placed crosswise on the ropes, and surrounded by a railing four feet high. There will be 10—6 over the river, and two between each tower and anchorage pier. Men will be stationed in them to regulate the weaving of the great cables. In the construction of the cables the wire will be first oiled while in the coils with one coat of raw and two coats of boiled linseed oil, by immersing it in oil and then hanging it to dry in the open air. The splices will be made to sustain a greater weight than the sound wire. Thirty-two wooden drums are on the Brooklyn anchorage, to hold the wires, each seven feet in diameter, sixteen inches wide in the clear, with rims eight inches deep. They are fitted with short handles, by which to turn them, and hung on horizontal iron shafts. Each drum, when full, will hold one ton of wire. Running out the wires is the next step, and men are stationed on the cradles to regulate it. The traveler carries the two wires across the river, and the motion is then reversed, carrying two more wires back from another drum; weaving strands of the cable. Iron saddles are placed upon the towers to hold the cables, which will be made in strands of convenient size, nineteen in all. When a strand is finished temporary wrappings of wire will be put on at intervals of sixteen or eighteen inches, to prevent the wire from being displaced by the wind, and the strand will be lowered to its place in the saddle and another commenced. The wires of each strand, while it is being made, rest on rollers above the groove in the saddle. The reasons for making the cables in strands at this greater elevation and greater tension are that any great imperfection in the wire will be revealed by the increased strain; the wind will have less effect, not causing it to sway; and the separation into strands enables the workmen to manage it better. The traveler makes about 165 round trips for each cable, laying two wires at a time, which makes 330 wires for a strand and 6,270 for a cable.

When all the requisite wires for a strand have been laid side by side, and as nearly in a round form as possible, and temporarily wrapped, the strand will be lowered to its proper deflection by bringing the "shoes" at each end forward and attaching them permanently to the anchor chains. The operation will be directed by signals made with small flags. When all the strands are finished and lowered to their positions, they will be relieved of the temporary wrappings, compressed into a circular form by heavy, wrought iron clamps, and then receive their final, spiral wrapping of one thickness of wire. The wrapping machine consists of a cast-iron cylinder in two halves, bolted together round the cable, which holds a wooden reel for the wrapping wire. It has a movable arm attached to a steel disk, which works on one end of the cylinder. The wire passes by a round turn around a little roller on one end of the movable arm, thence through a guiding slot in a steel disk, around the cable. By turning the arm the wire is wound around the cable and forces the machine along by its screw-like motion a distance equal to the thickness of the wire with every revolution, while by the turn around the little roller on one end of the arm the proper tension is maintained. The clamps are moved along the cable in advance of the wrapper, so as to keep the wires in their true position and form. From the cable is hung a "carriage" moving upon grooved wheels, in which the men stand while working the machine.

The point where all of the cables are made fast to the anchor chains is a short distance back of the face of the anchorage piers. They are compressed by the means of a permanent clamp at this point, and the spiral wrapping brought to the clamp. When all the rest of the work is completed, the ends of the cables, anchor chains, etc., will be entirely surrounded with and built up in the masonry yet to be done. When the cables have been finished, wrought iron bands will next be put around them, to which the suspenders are fastened which hold up the floor.—*Railway Review.*

AN OIL PIPE THREE HUNDRED MILES LONG.—The Pennsylvania Transportation Company, of which Mr. Henry Harley is president, has been chartered by the State of Pennsylvania for the purpose of transporting oil from the oil regions to the principal Atlantic seaboard cities. The plan proposed is to run the oil through a four inch pipe laid on the surface; the forcing power will be 900 lbs. to the square inch; there are to be stations at distances of fifteen miles, at each end of which an engine of 100-horse power will be erected to work a pump to continue the flow from point to point. The company having decided upon the construction of the work, the president sought the services of General Herman Haupt He pronounced the scheme, after a thorough examination, to be entirely practicable, and is now acting as engineer-in-chief. In view of the enormous product of oil in this country—30,000 barrels per day—and the rank it now holds among the leading articles of export, coupled with the exorbitant charges for railroad carriage from the wells to the seaboard, by the completion of the enterprise and its successful operation a complete revolution will be accomplished in the handling of this article. As a proof of how valuable this traffic has been to the several railroads over which the oil has been borne, it is only necessary to say that up to the present time the railroad charges aggregate $79,000,000. The minimum cost of

transporting oil by rail is 50 cents per barrel, and the minimum cost by the pipe process is 16 cents. The average charge by rail is $1.25.

The estimated cost of the entire work, including fixtures, etc., is $1,250,000; and considering the difference in cost between this method and that by rail, upon the hypothesis that the company will discount at least 25 cents a barrel on rail rates, it will readily be seen that, with all the expenses of operating, the first year's earnings will pay the first cost of the work. The Pennsylvania Company is the parent company, but there is also the Baltimore Transportation Company, chartered by the State of Maryland, and some five other companies are expecting to unite. The first objective point or terminus will be Baltimore, as being the most feasible and direct route for the pipes. Following which other termini will be established in Philadelphia, New York, etc.

The pipes being laid on the surface, and there being no obstacle in the way of forcing the oil to any height, the line will literally be an air line, and the distance from the oil regions to Baltimore is 300 miles. The oil will be distributed from the pipes into immense reservoirs, with refining establishments adjacent. Of course the whole railroad system will oppose it, for it is taking from them a traffic from the very nature of which there could be no competition; but the advantage to the oil producers, who will have the entire control, will be immense, and the advantages which will accrue from such facilities to this important branch of our export commerce will be incalculable.

The feasibility of this enterprize, so far as the passage of the oil through pipes is concerned, has been fully established by the present system in operation in the oil regions, where the aggregate length of the pipes conveying the oil from the several wells to the reservoirs is nearly 250 miles.—*Boston Traveler.*

[This method of transporting oil was originally suggested in this Magazine, in a series of articles on "Petroleum," contributed by Mr. Henry E. Wrigley, in 1872. This particular subject of transportation was discussed in the last of the series, published in the November number of that year.]

ORDNANCE AND NAVAL.

THE IRONCLADS OF EUROPEAN POWERS.—The recent discussion in the House on the subject of our own ironclad ships and those of other naval Powers has supplied the public with authentic information of a very interesting character at the present time. But the facts have presented some confusion owing to the circumstance that Mr. Reed, Mr. Goschen, Sir J. Hay, and Mr. Hunt, all reckoned up our ships on different principles, so that we are left in uncertainty as to whether we ourselves have twelve available ships, as stated by Mr. Reed, or twenty-nine, as enumerated by Mr. Hunt. The following account of our own fleet of armor-clad vessels may make the matter clear. We have certain powerful ships which are not completed, and are therefore not immediately available. Of these, Mr. Reed counted three, as likely to be shortly ready, the Dreadnought, Shannon, and Alexandra. The first named is to carry fourteen inches of armor. For immediate purposes, however, they must be thrown out of reckoning, and are only here mentioned to show that we are treating our own fleet in the same way as those of foreign Powers. To come then to the immediately available ships. We have the turret ships Devastation, Thunderer, and Glatton, carrying fourteen inch and twelve inch armor plates, and thirty and thirty-five ton guns, and the Cyclops, Gorgon, Hecate, and Hydra, carrying eight inches of armor and eighteen-ton guns. Of these, Mr. Reed counted only the Devastation and Thunderer as being really sea-going ships. At the same time there is little doubt that the remaining vessels which are of the Monitor class might be taken, as Mr. Samuda and Mr. Goschen pointed out, to the Mediterranean; and Mr. Reed himself counted vessels of a somewhat similar character in the available line of Turkish ships. Next may be enumerated the Hotspur and Rupert rams, with twenty-five and eighteen ton guns respectively, and armor ranging from twelve inches to eight inches in thickness. Both these are omitted by Mr. Reed, and counted by Mr. Samuda and Mr. Goschen as undoubtedly available. The Hercules and Sultan come next, carrying eighteen ton guns, and nine inches to six inches of armor; and the Monarch, turret ship, with twenty-five and twelve ton guns and seven inches of armor. These are thorough sea-going ships, and unimpeachable in all respects. The Bellerophon class may be taken next in order, consisting of the Bellerophon, Penelope, Invincible, Audacious, Iron Duke, Swiftsure, and Triumph. They carry generally twelve ton guns and six inches of armor. Some of these were included in Mr. Reed's list, but not all. After these might come the Warrior, Black Prince, Achilles, Defence, Resistance, Hector, Valiant, and Prince Albert, carrying chiefly nine ton guns and four and a half inches of armor; and the Minotaur, Agincourt, and Northumberland, with twelve and nine ton guns and five and a half inch plates. In addition to these there are the wood-built iron-plated ships Lord Warden, Royal Sovereign, Royal Alfred, and Repulse, with twelve and nine ton guns, and from six inches to four and a half inches of armor. The three last classes were not reckoned by Mr. Reed, either because he considered the guns too light, or because portions were unarmoured—as in the Warrior—or the vessel too long to be manageable, as in the case of the Minotaur class. Mr. Goschen and Mr. Samuda, however, again disagree with him. Lastly come some vessels with four and a half inches of armor, as the Royal Oak, the Research, Pallas, and Favorite, wood-built, and Viper, Vixen, Waterwitch, Scorpion, and Wyvern, iron built, which are still on our books, but not reckoned by any one. Of ironclad ships, then, the navy list contains forty-three of all classes, now available; and in discarding any from our reckoning, we must

bear in mind that the ships we throw out are only to be regarded as unfitted to cope with average modern ironclads, but still as more than a match for wooden ships, unless the latter carried specially heavy guns. Further, there are two causes that make it questionable how far ships are to be thrown out for insufficient thickness of armor: one, the circumstance that if a ship can fire so obliquely as to engage with her side inclined at an angle to her adversary beyond the glancing angle of shot it is a great question whether she would not be sufficiently protected by even very thin armor, and the other the fact that the vessel is unlikely to be identified by the enemy, and therefore any specially weak places, like those of the Warrior, might easily escape being struck, for they are not the parts that would ordinarily be aimed at. The above list, however, may be treated according to individual judgment; but if cut down to twelve in number, with Mr. Reed, it is to be remembered that there remain, left behind on our coasts, all the most powerful turret vessels and rams in our fleet.

The French fleet, as enumerated by Mr. Reed, consists of three vessels with eight and a half inches armor and twenty-one ton guns; three with twenty-one ton guns and seven inches armor; and three more with seven-three-quarter inches, six inches, and five inches armor and fourteen ton guns; and three with eight ton guns and six inches armor. On Mr. Reed's principle of reckoning, however, there are included among these some unfinished vessels, while, doubtless, the Solferino and Magenta class are thrown out. He mentions no names, but, of course, the Flandre, Belier, Marengo, and Taureau are included. Considering the large number of ironclad vessels that were built long since by the French, we may conclude that their fleet is curtailed in nearly the same ratio as our own if the newest and most powerful only be reckoned. Speaking generally, if a comparison be made between our own ironclads and those of the French, an inch must be added to our armor, because our ships have interior skins of from one and a half inches to five-eighth inches thick, which the French ships do not possess, to say nothing of the advantages in our mode of attachment of armor plates.

Of the Russian fleet, Mr. Reed reckons only five iron-clad sea-going ships as available by the end of the present year; but the Great Peter is not yet finished, and the Russian fleet at present available must chiefly consist of the vessels he throws out of the category of modern sea-going ironclads, either on account of imperfections in armor, or because they are chiefly intended for coast work, though probably the Novgorod and Admiral Popoff, with twenty-eight and forty-ton guns and eleven inches and eight inches armor respectively—the latter, we believe, is not finished—are included by him.

The Turkish fleet appears to be more powerful than is generally supposed. It consists of one ship carrying eighteen ton guns and twelve inches armor; four with twelve ton guns and five and a half inches armor; two smaller ones with twelve ton guns and nine inches armor; and lastly, two with twelve ton guns and seven inches armor, besides several smaller vessels each carrying a single twelve ton gun. Germany has six sea-going ironclads, and two building. Of these Mr. Reed says nothing. Probably the Konig Wilhelm, with eight inches of armor and ten inches backing, with one and a-half inches skin, is one of the most powerful. The Austrians have somewhat similar vessels in the Custozza, with nine inches of armor, and the Archduke Albrecht, with eight inches. Denmark we know to have nearly similar vessels. The powerful vessels ordered by Italy will not be completed for a long time. Her present fleet consists of four ships carrying twelve and a half ton guns and five inches of armor, together with older and inferior vessels. Mr. Reed estimates the various fleets in thousands of tons as follows: France, 84; Turkey, 59; Germany, 53; Italy, 37; Austria, 35; and Russia, 29. Mr. Hunt estimated our strength compared with that of France as 100 to 75.

Any estimate of this kind is difficult, and likely to be very arbitrary. Clearly, a fleet which possesses one or two ships with more powerful guns and much thicker armor than any of the enemy possesses a great advantage, but who is to say exactly what weight to attach to it? Speaking generally, the feature which is most surprising is the apparent weakness of Russia and the strength of Turkey on the sea.

BOOK NOTICES.

FILTH DISEASES AND THEIR PREVENTION. By JOHN SIMON, M. D., F. R. C. S. First American Edition. Boston: James Campbell. For sale by D. Van Nostrand. Price $1.00.

This work is well timed; the public mind is in condition to receive instruction in sanitary science, and the text book before us bears the stamp of competent authority. It has been written by "the Chief Medical Officer of the Privy Council and of the Local Government Board of Great Britain," and is published in this country under the direction of the State Board of Health of Massachusetts. These gentlemen urge public attention to this essay in the following terms:

"If the practical suggestions made therein were acted on by all citizens, hundreds of lives now annually doomed to destruction would be saved, and the health and comfort of the people greatly increased."

LESSONS IN ELEMENTARY MECHANICS. By PHILIP MAGNUS, B. A. With emendations and introduction by Prof. DE VOLSON WOOD. New York: John Wiley & Son. For sale by D. Van Nostrand. Price $1.50.

We had occasion, some months since, to notice the English edition of this little book. The American edition, with the indorsement of the author's method by Prof. Wood, is before us. The difference between the English book and its American reprint, is just that difference in mechanical execution which is generally found in comparing the scientific text-books of the two countries.

The "emendations" by Prof. Wood are not numerous; indeed, they are hard to find.

The recommendation by the Professor in his preface is valuable, and will aid in insuring a widespread use of the book which it certainly deserves.

INTRODUCTION TO THE STUDY OF CHEMICAL PHILOSOPHY. By WILLIAM A. TILDEN, F. C. S. New York: D. Appleton & Co. For sale by D. Van Nostrand. Price $1.50.

This is the latest addition to the list of Text-Books of Science, and is no less valuable than its predecessors. It is the most compact treatise on this subject with which we are acquainted; and as it is the latest contribution to chemical literature from a competent authority, it bears another recommendation to the student, which, in these times, he will not fail to recognize.

The problems for solution are numerous and excellent. We have, however, been accustomed to find in our old works more space given to Combustion and to Electrolysis than is afforded in this. On the other hand, the subjects of Isomerism and Dissociation are extended much beyond the limits heretofore assigned to them in books of this grade. Whether this work replaces those now in use or not as a class text-book, it will prove indispensable to the teacher.

THE INTERCOLONIAL: A Historical Sketch of the Inception, Location, Construction, and Completion of the Line of Railway uniting the Inland and Atlantic Provinces of Dominion of Canada. With maps and numerous illustrations. By SANDFORD FLEMING, C. E. Montreal: Dawson Brothers. For sale by D. Van Nostrand. Price $3.50.

The scope of this work is fully set forth in the above title. The author was the engineer-in-chief of the railway, and was consequently professionally interested in the compilation of the statistical information afforded to the reader.

The book has been made valuable to others than engineers. The topography and geology of the entire district is minutely described, with an abundance of maps and pictures rarely seen even in books of travel.

To the engineer the book possesses the value naturally inherent in all carefully described plans of the prominent workers in the profession.

The volume is made attractive by its binding and typography, as well as by the number and excellence of its photo-lithographic illustrations.

FIELD GEOLOGY. By W. Henry Penning, F. G. S. London: Bailliere, Tindall & Cox. For sale by Van Nostrand. Price $3.75.

It is explained by the author in the preface to this little practical treatise, that the original plan was to publish a few plain instructions for making surveys of the surface geology and establishing boundary lines, but finding the connection between this work and tracing formations below the surface so intimate, he expanded the book beyond its original dimensions; and he adds: "There are so many subjects of which a knowledge is an advantage in geological surveying, that it is difficult to say what ought not to be included in a book on Field Geology."

Our examination leads us to believe that the author could do very much better if he should try again. As the work stands now, it affords good suggestions to those who are experienced field surveyors already, but is of little or no use to others. The detailed description of field operations might, therefore, have been omitted.

The chapter on Lithology, although containing many good suggestions, would afford but little valuable aid to a learner in the determination of common rocks.

Forty pages are occupied with a list of fossils with no word of description. but arranged alphabetically, and its geological position given, "so that," the author remarks, "if a fossil be known, the approximate (if not exact) geological position of the rock from which it was derived can readily be determined." It will occur at once to the learner, that as he must at any rate go to the works on Paleontology to identify a fossil, and then such works invariably give the locality of the fossil, the space devoted to the bare list might have been spared in this little volume.

Still the book is of considerable value for the suggestions it affords in regard to the objects to be accomplished: It is deficient in its teaching how to go to work. The author is, doubtless, an experienced geologist, but he is not an efficient instructor.

THE ETHICS OF BENEDICT DE SPINOZA. From the Latin, with an Introductory Sketch of his Life and Writings. New York: D. Van Nostrand. Price $3.50.

This is the first translation of Spinoza's works that has been published in this country. To readers that delight in so abstruse a subject, and, at the same time, lean favorably towards the geometrical methods of reasoning, may here find an enjoyable treat.

The system is developed strictly after the method of geometry, in numbered propositions, and divided into five parts, as follows:

Part I. Of God; Part II. Of the Nature and Origin of the Soul; Part III. Of the Origin and Nature of the Affections or Passions; Part IV. Of Man's Slavery or the Force of the Passions; Part V. Of Man's Freedom or the Power of the Understanding.

An exceedingly well printed volume of 376 pages.

MISCELLANEOUS.

WOODEN DOWELS.—In the ancient Egyptian temples, stones have been found tied together by a kind of dowel of wood on their upper surfaces, and these wooden ties, of dovetail form, were inserted about an inch deep. Some of these have been found quite sound in temples known to be at least four thousand years old. The ties are said to be the tamarisk or Shittim wood, of which the ark was constructed, and which was a sacred tree in ancient Egypt, though now very rarely found.